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ACTICE IN EUROPE
WITH
Y RIFLED GUNS

OARD OF ENGINEERS
1883

No. 25.

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1883.

PROFESSIONAL PAPERS OF THE CORPS OF ENGINEERS, U. S. ARMY.

No. 25.

REPORT

UPON THE

PRACTICE IN EUROPE

WITH THE

HEAVY ARMSTRONG, WOOLWICH, AND KRUPP

RIFLED GUNS,

SUBMITTED BY

THE BOARD OF ENGINEERS FOR FORTIFICATIONS.

COLONEL Z. B. TOWER, CORPS OF ENGINEERS,
BREVET MAJOR-GENERAL, U. S. A.,
PRESIDENT OF THE BOARD.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1883.

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Gen

The Chief of Engineers.

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OFFICE OF THE CHIEF OF ENGINEERS,
UNITED STATES ARMY,
Washington, D. C., January 30, 1883.

SIR: The Board of Engineers has submitted a report presenting records collected from time to time of practice abroad with the heavy Armstrong, Woolwich, and Krupp rifled guns. The results are tabulated for easy reference, and exhibit a large range in powder charges, initial velocities, and striking energies of the projectile from the earlier to the latest trials.

The paper contains valuable information for the officers of the Corps of Engineers and for the Army generally, and I respectfully recommend that authority be granted to have it printed, with its accompanying plates, at the Government Printing Office, as a Professional Paper of the Corps of Engineers, and that 1,000 copies be obtained for the use of the Engineer Department upon the usual requisition.

In view of the permanency of its value, and to save expense of "composition," in case that future editions are called for, I further recommend that the work be stereotyped.

The report, with accompanying tables and plates, is submitted herewith.

Very respectfully, your obedient servant,

H. G. WRIGHT,
Chief of Engineers,
Brig. and Bvt. Maj. Gen.

Hon. ROBERT T. LINCOLN,
Secretary of War.

[First indorsement.]

Approved.

By order of the Secretary of War.

JOHN TWEEDALE,
Chief Clerk.

WAR DEPARTMENT,
February 1, 1883.

REPORT.

OFFICE OF BOARD OF ENGINEERS FOR FORTIFICATIONS
AND FOR RIVER AND HARBOR IMPROVEMENTS, &c.,
Army Building, New York, January 9, 1883.

GENERAL: On the part of the Board of Engineers for Fortifications, I have the honor to present the following records, collected from time to time, of practice abroad with the heavy Armstrong, Woolwich, and Krupp rifled guns. The results are tabulated for easy reference. They exhibit a large range in powder charges, in initial velocities, and striking energies of the projectile, from the earlier to the latest trials. In fact, the power of these guns, as expressed in foot-tons, has been about doubled by the increased powder charges which have been recently tried, without apparent injury to the guns themselves. In the text following the tables are given—

1st. The practice of the English guns against shields of wrought iron and of steel, in England and at Spezzia, in 1876–'7, and the Meppen trials with Krupp's 18-ton gun.

2d. Trials of compound armor of iron and steel made in England and in France.

3d. The recent experiments at Spezzia with the 100-ton Armstrong gun against single plates of wrought iron, faced with steel, and a plate wholly of hammered steel.

4th. Trials with Gruson's chilled cast-iron embrasure shield.

The record is thus brought down to the present day.

Mr. Diezelski, draughtsman to the Board, has calculated, by the aid of Krupp's ballistic tables, from velocities actually attained in firing the 100-ton gun Armstrong, the 81 and 38 ton Woolwich, and the 70, 51, and 18 ton Krupp guns, as well as the 8-inch converted United States rifle, the final velocities for ranges from 600 to 6,000 yards.

By the earlier Royal Artillery formula, wrought out from practice against iron targets built up of thin plates, he has calculated the thickness of shields just penetrable by the projectiles of those guns for the above specified ranges. Similar calculations have also been made, using the later formula for penetration founded upon experimental firing against thick iron plates. These results, with the velocities, are tabulated for ready use, and are illustrated by the curves of Sheets I and II. Sheet III gives the penetration of projectiles for energies per inch of shot's circumference, varying from 0 to 1,000 tons, as against the two classes of targets mentioned.

Though in the future plates of improved manufacture and of greater thickness will probably be used, both in the construction of ships and forts, the above tables of

penetrations will be useful as giving the resistances of naval armor as hitherto applied, and of iron shields, so far as they have been introduced into the construction of sea-coast defenses up to this date.

The earlier trials of armor plates in England, which are not included in the above, were made to test the resistance of their iron-plated ships as constructed up to that time, but more especially to arrive at a better quality of iron for plates, and the best manner of putting them together, whether as armor for ships or as shields for embrasures in the construction of sea-coast forts. Those experiments led to the production of plates more resisting, less liable to be cracked by the striking shot, and of such increased thickness that the leading iron-manufacturing establishments of England furnished for trial at Spezzia in 1876 plates 22 inches thick of excellent quality. But neither those thick wrought-iron plates, nor a cast-steel plate made at Creusot, France, of the same thickness, could stop the projectile of the 100-ton Armstrong gun. The first were penetrated; the latter was broken up.

Thus the result aimed at had not yet been reached, viz: to so improve the material for the construction of armor plates as to render them impenetrable by the heaviest projectiles in use if limited to thicknesses suitable for armoring ships as at that time designed. Further experiments were therefore instituted to test a combination of the two materials, wrought iron and steel, and with good results, the compound armor-plates resisting better than those of homogeneous iron. Those trials, confined to comparatively thin plates, probably led to the late experiments at Spezzia, which were conducted on a scale better suited to solve finally the problem enunciated above.

To summarize:

Experimental firings for penetration during the past twenty years have determined that wrought iron and cast iron, unless chilled, are unsuitable for projectiles to be used against iron armor; that the best material for that purpose is hammered steel or Whitworth's compressed steel.

2d. That cast-iron and cast-steel armor-plates will break up under the impact of the heaviest projectiles now in service unless made so thick as to exclude their use in ship protection.

3d. That wrought-iron plates have been so perfected that they do not break up, but are penetrated by displacement or crowding aside of the material in the path of the shot, the rate of penetration bearing an approximately determined ratio to the striking energy of the projectile, measured per inch of shot's circumference, as expressed by the following formula:

$$\text{Penetration} = \sqrt[2.035]{\frac{V^2P}{2g \times 2r\pi \times 2240 \times 0.86}} \text{ in inches.}$$

V = velocity in feet per second; P = weight of shot in pounds; r = radius of shot in inches.

That such plates can, therefore, be safely used in ship construction, their thickness being determined by the limit of flotation and the protection needed.

4th. That though experiments with wrought-iron plates, faced with steel, have not been sufficiently extended to determine the best combination of these two materials,

we may nevertheless assume that they give a resistance about one-fourth greater than those of homogeneous iron.

5th. That hammered steel in the late Spezzia trials proved superior to any other material hitherto tested for armor-plates. The 19-inch plate resisted penetration, and was only partially broken up by four shots, three of which had a striking energy of between 33,000 and 34,000 foot-tons each. Not one shot penetrated the plate. Those of chilled iron were broken up, and the steel projectile, though of excellent quality, was set up to about two-thirds of its length. This experiment seems to promise the solution of the problem to determine a material for armor-plates which, though limited in thickness to the carrying capacity of the ship to be protected, will still have sufficient resistance to break up the projectiles of the largest guns now in the naval service, without being penetrated or broken by the projectile.

It seems probable that a hammered-steel plate, like that tried at Spezzia, if equal in thickness to the belt armor of the Inflexible (22 inches), would stop the shot of the 100-ton gun (Armstrong), fired with its greatest practicable velocity.

Finally, these later experiments confirm this Board in its opinion, enunciated some years since, that while the 12-inch rifled gun may prove a sufficient armament for the barbette batteries of our sea-coast defenses, as against the lighter iron-clads of foreign navies, iron turrets, armed with guns of 100 tons weight at least, will be needed to meet the attack of armored ships of the latest construction.

The accompanying notes, prepared for the use of the Board, if printed, may prove of some use to the officers of the Corps of Engineers, and especially to those whose duties for many years have prevented them from taking any part in the discussion of the subject of sea-coast defenses or in their construction.

Respectfully submitted.

Z. B. TOWER,
Colonel of Engineers and Brevet-Major General,
President of Board.

Brig. Gen. H. G. WRIGHT,
Chief of Engineers, U. S. A.,
Washington, D. C.

RECORD OF FIRING OF THE 100-TON ARMSTRONG GUN.

[Caliber in 1876, 17 inches; in 1879 and 1882, 17.75 inches. Length of bore, 30.5 feet. Diameter of powder-chamber in 1879, 19.75 inches. Length of bore in 1879, 33 feet.]

Date of firing.	Ammunition.				Performance.			Remarks.
	Kind of powder.	Weight of powder charge.	Kind of projectile.	Weight of projectile.	Initial velocity per second.	Initial energy.	Energy per inch of shot's circumference.	
				P	V	$\frac{PV^2}{2g\,2240}$	$\frac{PV^2}{2g\,2\pi\,2240}$	
		Pounds.		*Pounds.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	
October 23, 1876	1.5-inch cubes, Waltham Abbey.	330	...	2,000	1,446	28,990	544.05	
	....do	300		2,000	1,374	26,175	490.10	
	....do	330		2,000	1,456	29,391	550.30	
	....do	319		2,000	1,422	28,035	525.00	
October 26, 1876	.. .do	319		2,000	1,437	28,625	535.97	
	....do	340		2,000	1,475	30,163	564.80	Against Schneider steel.
October 27, 1876	....do	341		2,000	1,478	30,296	567.33	Against Cammell iron plate.
	....do	341		2,000	1,490	30,789	576.57	
	....do	341.6		2,000	1,500	31,200	584.19	Against Marrel iron plate.
October 28, 1876	....do	341.6		2,000	1,493	30,920	578.95	Against Schneider steel plate.
	....do	341.6		2,000	1,492	30,880	578.20	Against Marrel Sandwich target.
November 2, 1876	....do	319		2,500	1,294	29,027	543.50	
	....do	319		2,500	1,293	29,000	543.00	
	....do	319		2,500	1,293	29,000	543.00	
November 7, 1876	....do	353		2,000	1,512	31,705	593.72	
	....do	364		2,000	1,514	31,789	595.29	
	... do	375		2,000	1,543	33,000	623.00	
November 8, 1876	Fossano ...	319		2,000	1,348	25,200	471.91	
	....do	341		2,000	1,415	27,760	519.85	
	....do	363		2,000	1,408	27,500	514.91	
	....do	363		2,000	1,444	28,900	541 12	
December 14, 1876	....do	240		2,000	1,050	15,287	286.24	Cammell Sandwich target.
	....do	400		2,000	1,494	30,950	579.51	Gregorini Sandwich target.
	...do	400		2,000	1,502	31,282	585.74	Plate upon plate, Gregorini target.
	....do	240		2,000	1,062	15,639	292.82	Brown-iron plate.
	....do	400		2,000	1,499	31,157	583.40	Do.
	1.5-inch cubes, W. A.	264		2,000	1,299	23,398	438.11	Do.
April, 1879		572		1,997	1,716	40,785	731.45	
June 23, 1879		550	Gregorini	2,022	1,715	41,241	739.57	See Note A.
		550	Whitworth	2,110	1,673	40,966	734.65	See Note B.
		550	Armstrong	1,946	1,736	40,653	729.07	See Note C.
(?)		463		2,010	1,645	37,721	676.09	
	Fossano	550		2,000	1,700	40,000	717.31	
1882		776		2,000	1,832	46,580	835.32	Highest energy.

NOTE A.—Fired against a steel plate 27.55 inches thick; penetrated 14 inches; projectile rebounded.
NOTE B.—Fired against same plate; pierced plate and backing, projectile remaining whole.
NOTE C.—Fired against same plate; penetrated 11.8 inches. Plate destroyed with this round.

RECORD OF FIRING OF THE 81-TON WOOLWICH GUN.

[Length of bore, 24 feet.]

Date of firing.	Ammunition. Kind of powder.	Ammunition. Weight of powder charge.	Ammunition. Kind of projectile.	Ammunition. Weight of projectile. P	Performance. Initial velocity per second. V	Performance. Initial energy. $\frac{PV^2}{2g2240}$	Performance. Energy per inch of shot's circumference. $\frac{PV^2}{2g\,2\pi\,2240}$	Remarks.
		Pounds.		*Pounds.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	
September, 1875	¾-inch cubes	170		1,258	1,393	16,922	371.50	
	do	210		1,258	1,475	18,972	416.51	
	do	220		1,254	1,503	19,637	431.11	
	do	230		1,260	1,550	20,984	460.68	
	do	240		1,258	1,550	20,951	459.95	
November and December, 1875	1.5-inch cubes	220		1,260	1,525	20,313	445.94	
	1.7-inch cubes	220		1,260	1,420	17,612	386.66	
	do	230		1,260	1,454	18,465	405.39	
	do	240		1,260	1,470	18,874	414.37	
	1.5-inch cubes	220		1,260	1,505	19,784	434.33	Unchambered; caliber, 14.5 inches.
	1.7-inch cubes	220		1,260	1,502	19,705	432.59	
	2-inch cubes	220		1,260	1,481	19,157	420.60	
	1.7-inch cubes	230		1,260	1,543	20,796	456.54	
	2-inch cubes	230		1,260	1,498	19,598	430.30	
	do	240		1,260	1,513	19,995	438.95	
	1.5-inch cubes	220		1,450	1,440	20,842	457.57	
	1.7-inch cubes	220		1,450	1,414	20,097	442.22	
	2-inch cubes	220		1,450	1,366	18,756	411.75	
	do	250		1,260	1,523	20,259	444.78	
March, 1876	1.7-inch cubes	220		1,260	1,513	19,995	424.32	
	do	230		1,260	1,546	20,789	441.19	
	do	220		1,460	1,471	21,907	464.92	
	2-inch cubes	250		1,260	1,536	20,607	437.33	
	do	220		1,460	1,364	18,829	399.59	
	1.7-inch cubes	220		1,460	1,424	20,529	435.60	
April, 1876	do	250		1,466	1,459	21,645	459.33	
	2-inch cubes	250		1,466	1,408	20,159	427.77	
	1.7-inch cubes	260		1,466	1,466	21,854	463.74	Unchambered; caliber, 15 inches.
	2-inch cubes	260		1,466	1,423	20,590	436.93	
	1.7-inch cubes	270		1,466	1,484	22,377	475.20	
	2-inch cubes	270		1,466	1,440	21,085	447.43	
	1.5-inch cubes	250		1,466	1,451	21,409	454.31	
	1.7-inch cubes	280		1,466	1,495	22,718	482.26	
	1.5-inch cubes	260		1,466	1,474	22,093	468.82	
	2-inch cubes	280		1,466	1,456	21,556	457.43	
	1.5-inch cubes	270		1,466	1,491	22,606	479.7	
May and June, 1876	do	260		1,466	1,480	22,278	472 64	
	1.7-inch cubes	260		1,466	1,473	22,062	468.19	
	2-inch cubes	260		1,466	1,424	20,619	437.53	
	1.5-inch cubes	270		1,466	1,499	22,848	484.85	
	1.7-inch cubes	270		1,466	1,488	22,514	477.75	
	2-inch cubes	270		1,466	1,446	21,262	451.18	
	1.5-inch cubes	280		1,466	1,534	23,900	507.76	
	1.7-inch cubes	280		1,466	1,509	21,355	491.34	
	2-inch cubes	280		1,466	1,462	21,735	461.22	
	1.5-inch cubes	280		1,466	1,524	23,616	501.16	Diameter of chamber, 16 inches; caliber, 15 inches.
	1.7-inch cubes	290		1,466	1,522	23,554	499.83	
	2-inch cubes	290		1,466	1,474	22,093	468.82	
	1.5-inch cubes	300		1,466	1,526	23,679	502.46	
	1.7-inch cubes	300		1,466	1,531	23,835	505.79	
	2-inch cubes	300		1,466	1,475	22,123	469.45	
	1.5-inch cubes	310		1,466	1,553	24,508	520.40	
	do	300		1,466	1,535	23,960	508.42	
	1.7-inch cubes	310		1,466	1,551	24,461	519.08	

RECORD OF FIRING OF THE 81-TON WOOLWICH GUN—Continued.

Date of firing.	Ammunition.				Performance.			Remarks.
	Kind of powder.	Weight of powder charge.	Kind of projectile.	Weight of projectile.	Initial velocity per second.	Initial energy.	Energy per inch of shot's circumference.	
				P	V	$\frac{PV^2}{2g2240}$	$\frac{PV^2}{2g2\pi r2240}$	
		Pounds.		*Pounds.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	
May and June, 1876	1.5-inch cubes	300		1,466	1,532	23,866	506.44	
	1.7-inch cubes	290		1,466	1,521	23,524	499.2	
	1.5-inch cubes	310		1,466	1,551	24,461	519.08	
July, 1876	do	250		1,700	1,384	22,577	449.11	
	do	260		1,700	1,396	22,970	456.97	
	do	270		1,700	1,411	23,466	466.84	
	do	280		1,700	1,426	23,968	476.40	
	do	290		1,700	1,452	24,850	494.40	
	do	300		1,700	1,458	25,055	498.44	
	do	300		1,700	1,442	24,509	487.61	
	do	310		1,700	1,462	25,193	501.20	
	do	320		1,700	1,469	25,435	506.02	
	do	300		1,700	1,437	24,339	484.21	
	do	330		1,700	1,479	25,782	512.92	Unchambered; caliber 16 inches.
	do	340		1,700	1,494	26,308	523.40	
	do	320		1,700	1,472	25,539	508.08	
August and September, 1876.	do	340		1,700	1,486	26,030	517.85	
	do	350		1,700	1,505	26,740	531.98	
	do	350		1,700	1,502	26,630	529.79	
	do	350		1,700	1,467	25,406	505.44	
	do	350		1,700	1,475	25,683	510.95	
	do	360		1,700	1,487	26,103	519.30	
	do	370		1,700	1,523	27,383	544.77	
	do	360		1,700	1,518	27,203	541.19	
	do	370		1,700	1,519	27,239	541.90	
	do	370		1,700	1,517	27,168	540.49	
February, 1877	do	370	Palliser shell	1,700	1,510	27,000	537.00	Unchambered; caliber, 16 inches; penetrated 25.5 inches wrought iron.
May, 1877	do	425	do	1,700	1,600	30,180	600.3	Caliber, 16 inches; penetrated 26 inches wrought iron; diameter of chamber, 18 inches.
	do	425		1,700	1,586	29,651	589.88	Mean of four rounds. Caliber, 16 inches.
	do	335		1,550	1,603	27,600	566.79	Caliber, 15.5 inches; unchambered.
	do	335		1,550	1,599	27,480	564.33	
	do	335		1,550	1,598	27,443	563.57	
September, 1879		425		1,760	1,603	31,361	623.91	Caliber, 16 inches; diameter of chamber, 18 inches.
		445		1,760	1,657	33,710	667.1	

81-TON WOOLWICH GUN.

[Caliber, 16 inches.]

Table giving elevations, time of flight, and first graze of projectiles.

Date of firing.	Ammunition.			Performance.			Remarks.
	Weight of powder charge.	Weight of projectile.	Kind of projectile.	Elevation.	First graze.	Time of flight.	
	Pounds.	*Pounds.*		°	*Feet.*	*Seconds.*	
September and October, 1876...	370	1,700	Palliser shell.....	1	3,291	2.2	Greatest distance reached by shells upon ricochet.
	370	1,700	.....do	1	3,240	2.2	
	370	1,700	.....do	1	3,315	2.3	
	370	1,700	.....do	1	3,318	2.2	
	370	1,700	.. ...do	1	3,318	2.2	
	370	1,700	Common shell	3	7,035	5.2	
	370	1,700	.....do	3	7,110	5.4	
	370	1,700	... ..do	3	7,053	5.3	
	370	1,700	.....do	3	6,996	5.2	
	370	1,700	.....do	3	6,993	5.2	
	370	1,700	Palliser shell....	4	9,111	6.8	
	370	1,700	... ..do	4	9,084	6.9	Loading by hand, timed, found to take 2¾ minutes.
	370	1,700	... ..do	4	9,231	6.6	
	370	1,700	.....do	4	9,288	7.1	
	370	1,700	.....do	4	9,237	6.7	
	370	1,700	.....do	7	14,061	11.4	
	370	1,700	.....do	7	14,151	11.3	
	370	1,700	... . do	7	14,016	11.4	
	370	1,700	.....do	7	14,097	11.4	
	370	1,700	.....do	7	14,400	11.2	
	370	1,700	Palliser chilled shell	7	14,049	11.2	
	370	1,700	.....do	7	14,355	11.4	
	370	1,700	. ....do	7	14,028	11.3	
	370	1,700	.....do	7	14,388	11.5	
	370	1,700	.....do	7	14,337	11.3	
	370	1,700	Palliser shell.....	10	18,750	15.5	Projectile made a crater in sand 27 feet long, 13 feet wide, 9 feet deep.
	370	1,700	.....do	10	18,753	15.5	
October, 1879	425	1,700	.....do	1	3,363	2.3	
	425	1,700	.....do	1	3,441	2.3	
	425	1,700	.....do	3	7,575	5.2	
	425	1,700	.....do	3	7,749	5.5	

RECORD OF FIRING OF THE 38-TON WOOLWICH GUN.

[Caliber, 12.5 inches. Length of bore, 16.5 feet.]

Date of firing.	Ammunition.				Performance.			Remarks.
	Kind of powder.	Weight of powder charge.	Kind of projectile.	Weight of projectile.	Initial velocity per second.	Initial energy.	Energy per inch of shot's circumference.	
				P	V	PV^2 / $2g$ 2240	PV^2 / $2g\pi$ 2240	
		Pounds.		*Pounds.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	
October, 1876	1.5-inch cubes	130	Palliser shell	800	1,451	11,688	297.64	Gun unchambered.
October, 1880	do	200		800	1,590	14,203	357.4	Gun chambered; diameter, 14 inches.
					At target, 210 feet from gun.			
October, 1876	do	130	Palliser shell	800	1,421	11,210	285.4	Penetrated 19½ inches wrought iron and 10 inches of wood; gun unchambered.
October, 1877	do	200	do	800	1,525	13,080	333.0	Penetrated 20.5 inches wrought iron and 15 inches of wood. Gun chambered; diameter, 14 inches.
					At target, 227 feet from gun.			
October, 1880		180	Palliser	828	1,504	12,545	319.4	Fired against 18-inch compound armor; shot broke up. Gun chambered; diameter, 14 inches.

RECORD OF FIRING OF THE 42-CENTIMETER (71-TON) KRUPP GUN.

[Caliber, 15 75 inches. Length of bore, 28.58 feet. Diameter of powder-chamber, 17.32 inches.]

May 3, 1879	Prism. A	298	Plain	1,707	1,184	16,602	335.42	
	Prism. C.	385	do	1,688	1,132	14,995	303.43	
	do	485	do	1,701	1,427	24,028	485.50	
	Prism. S	397	do	1,700	1,593	29,909	604.41	
	do	419	do	1,694	1,641	31,645	639.68	
	Prism. D	440	do	1,713	1,652	32,415	656.10	
	Prism. H	440	do	1,694	1,642	31,696	640.50	
	Prism. 2-inch R.	440	do	1,694	1,645	31,796	642.96	
July 16, 1879	Prism. H	441	Shrapnel	1,712	1,622	31,237	631.48	
	do	463	do	1,704	1,668	32,895	665.10	
	do	485	do	1,715	1,703	34,503	697.91	Highest energy.
	Prism. 2-inch R.	441	do	1,715	1,623	31,283	632.30	
	do	441	do	1,711				
	do	441	do	1,715				
	do	441	do	1,712				
	do	452	do	1,711	1,640	31,928	645.42	
August 5, 1879	Prism. 1 hole	452	do	1,715	1,648	32,264	651.98	
	do	452	do	1,711				
	do	452	do	1,714				
	do	452	do	1,713				
	do	452	do	1,709				
August 6, 1879	Prism. 2-inch, 1 hole	441	Common shell	1,419	1,761	30,484	616.14	Highest velocity.
	do	441	do	1,415				
	do	441	do	1,419				
	do	441	do	1,418				
	do	441	do	1,415				

RECORD OF FIRING OF THE 35.5-CENTIMETER (51-TON) KRUPP GUN.

[Caliber, 14-inch = 2 r. Length of bore, 25.39 feet. Diameter of powder-chamber, 14.38 inches.]

July 2, 1878	Prism. 1 hole	254	Chilled steel	1,257.5	1,631	21,372	486.64	Mean of 10 rounds.
(?)	(?)	298	(?)	1,246.4	1,645	21,528	489.5	

RECORD OF FIRING OF THE 24-CENTIMETER (18-TON) KRUPP GUN.

[Caliber, 9.45 inches. Length of bore, 17.5 feet. Diameter of powder-chamber, 11.25 inches.]

Date of firing.	Ammunition.				Performance.			Remarks.
	Kind of powder.	Weight of powder charge.	Kind of projectile.	Weight of projectile.	Initial velocity per second.	Initial energy.	Energy per inch of shot's circumference.	
				P	V	$\frac{PV^2}{2g2240}$	$\frac{PV^2}{2g\pi 2240}$	
		Pounds.		*Pounds.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	
December 14, 1878	Prism. 1 hole	132	Plain, with copper band.	300	1,873	7,298	246.03	
	do	154	do	299	2,047	8,683	291.22	
	do	165	do	300	1,978	8,138	274.08	
	do	172	do	309	2,001	8,573	288.76	
	do	172	do	354	1,913	8,978	302.37	
January 16, 1879	Prism. H	165	Shrapnel; length, 3¾ cal.	475	1,673	9,220	310.74	
	do	165	do	475				
	do	165	do	474				
May 12, 1879	Prism. 2-in. R.	110	Shrapnel; length, 2.8 cal.	364	1,476	5,499	185.35	
	do	165	do	365	1,885	8,996	303.19	
	do	165	do	365				
	do	165	Shrapnel, 3¾ cal.	474	1,688	9,367	315.66	Highest energy.
	do	165	do	474				
	do	172	Shrapnel, 2.8 cal.	366	1,910	9,260	312.05	
	do	176	Common shell, 2.8 cal.	308	2,087	8,997	303.19	Highest velocity.
August 7, 1879	Prism. 1 hole	165	Shrapnel	353	1,892	8,754	294.91	
	do	165	do	353				
	do	165	do	353				
	do	165	do	353				
	do	165	do	353				
	do	165	Common shell.	300	1,991	8,244	277.69	
	do	165	do	300				
August 8, 1879	do	165	Krupp steel shell.	348	1,888	8,594	289.50	
	do	165	do	347				
	do	165	do	348	1,901	8,725	293.92	Penetrated 20 inches of wrought iron and went 7,218 feet beyond.
	do	165	do	347	1,876	8,473	285.41	Penetrated 20 inches of wrought iron and went 3,937 feet beyond.

PENETRATION OF ARMOR.

(Plate I.)

Trials of the 100-*ton gun* (Armstrong), at Spezzia, 1876 and 1879. Thickness of plates, 22 inches.

The 81-*ton gun*, at Shoeburyness, 1877. Thickness of plates, 32 inches.

The 38-*ton gun*, at Shoeburyness, 1876–'77. Thickness of plates, 19.5 inches, 26 inches.

The 18 *and* 25 *ton guns*, at Spezzia, 1876. Thickness of plates, 22 inches.

The 24-*centimeter* (9.45 *inches*) 18-*ton Krupp gun*, Meppen trials, 1879. Thickness of plates, 20 inches.

REFERENCES.—"Engineering," Vols. XXII, XXIII, XXVII; King's "Navies of the World;" "The British Navy," by Sir Thomas Brassey, K. C. B.; Krupp's publication, "Expériences de tir exécutées au polygone de Meppen au mois août 1879;" Gruson's publication, "Schiessversuche gegen Panzer," by Otto von Geise.

PENETRATION OF ARMOR—100-TON GUN.

First round. Fired at Spezzia, 1876.

Weight of shot, 2,000 pounds; powder charge, 340 pounds; range, 100 yards; initial velocity, 1,495 feet; striking velocity, 1,463 feet; total striking energy, 29,370 foot-tons; striking energy per inch of shot's circumference, 550 foot-tons.

DESCRIPTION OF TARGET.

The target was a steel plate from Schneider, at Creuzot, 22 inches thick, 12 feet long, 4 feet 8 inches high, with 28.8 inches of wooden backing, in rear of which were two iron plates, together 1½ inches thick, the whole backed by a ship's frame.

EFFECTS.

(Fig. 10.)

Utter destruction of steel plate, but backing not perforated, the shot entering the wood to a depth of 22 inches. The framing was dangerously bulged and torn.

Another shot, with 1,490 feet initial velocity, 2,000 pounds weight, fired against a second steel plate, previously fired at by 10-inch and 11-inch guns, produced same effects as foregoing round.

Second round.

Weight of shot, 2,000 pounds; powder charge, 341 pounds; range, 100 yards; initial velocity, 1,478 feet.

DESCRIPTION OF TARGET.

The target consisted of a rolled iron plate (Cammell), 22 inches thick, 12 feet long, 4 feet 8 inches high, 28.8 inches wooden backing, 1½ inches iron skin, the whole backed by a ship's frame.

EFFECTS.

(Fig. 9.)

The shot penetrated the target completely with a remaining velocity of 650 feet, or about 5,500 foot-tons energy, leaving a hole nearly 4 feet in diameter in center of target.

Half the plate was struck away, leaving the wood bare.

Third round.

Weight of shot, 2,000 pounds; powder charge, 341 pounds; range, 100 yards; velocities higher; energies not given.

DESCRIPTION OF TARGET.

The target consisted of a rolled iron plate (Marrel), 22 inches thick, 28.8 inches wooden backing, 1½ inches iron skin, backed by a ship's frame.

EFFECTS.

(Fig. 9.)

The target was utterly destroyed. The shot passed completely through, leaving a large hole in the center of the target.

Fourth round.

Weight of shot, 2,000 pounds; powder charge, 341 pounds; range, 100 yards; velocities and energies not given.

DESCRIPTION OF TARGET.

The target consisted of two rolled iron plates (Marrel); front plate, 12 inches thick; wooden backing, 12 inches; rear plate, 10 inches thick; wooden backing, 16 inches; iron skin, 1½ inches, backed by a ship's frame.

EFFECTS.

(Fig. 11.)

The target, previously injured by 10-inch and 11-inch guns, was utterly destroyed and complete penetration obtained. The main part of the target was carried away by the shot.

Fifth round.

Weight of shot, 2,000 pounds; powder charge, 240 pounds (Fassano); velocity, 1,050 feet; range and energy not given.

DESCRIPTION OF TARGET.

The target consisted of two rolled iron plates (Cammell), front plate 12 inches thick, 12 inches wooden backing, with iron stringers; behind this a 10-inch plate, 16-inch wooden backing, 1½ inches iron skin, backed by a ship's frame.

EFFECTS.

The shot passed through front plate, cracked it through from top to bottom, penetrated wooden interior, and entered 6.8 inches into rear plate. Base of shell broke up and the remainder was starred. The iron skin was cracked and an iron beam behind was doubled up.

Total iron penetration, 18.8 inches.

Sixth round.

The next round fired was against a solid 22-inch plate (Brown), same charge as preceding round. The shot hit the plate at its lower edge, broke up into several pieces, which were deflected downwards, making a hole in the ground 6 to 8 feet deep in a slanting direction under the target. Though lost for the immediate object of experiment, this round was of great interest, for it showed that a shell striking the edge of a narrow belt of armor, which will soon be all that ships can afford to carry, will pierce engine-rooms and boilers and pass out below the water-line on the other side.

Seventh round.

Weight of shot, 2,000 pounds; powder charge, 400 pounds (Fassano); velocity, 1,494 feet; range and energy not given.

DESCRIPTION OF TARGET.

The target consisted of an 8-inch wrought-iron front plate, 12 inches wood, 14 inches chilled-iron plate (Gregorini), 16 inches wooden backing, 1½ inches iron skin, backed by a ship's frame.

EFFECTS.

The shot penetrated target completely, and caused more terrible ruin behind it than had occurred in any previous experiment. The shell was broken up into many pieces, which dashed through into the interior of the ship, carrying with them a great number of ragged fragments of broken plate.

Eighth round.

Weight of shot, 2,000 pounds; powder charge, 400 pounds (Fassano); velocity, 1,502 feet; range and energy not given.

DESCRIPTION OF TARGET.

The target consisted of two plates, without any teak between them. The front plate, made of wrought-iron, was 8 inches in thickness; the cast-iron rear plate, 14 inches; 28 inches wooden backing, 1½ inches iron skin, and a ship's frame completed the target.

EFFECTS.

The target was completely penetrated and ruined; a large portion of the front plate was torn off, and fragments of cast iron were driven forward and out of the sides of the target.

Three rounds were fired at a solid "Brown" plate.

DESCRIPTION OF TARGET.

The target consisted of a solid rolled iron plate (Brown), 22 inches thick, 28 inches wooden backing, 1½ inches iron skin, and a ship's frame.

Ninth round.

First round: Weight of shot, 2,000 pounds; powder charge, 240 pounds; velocity, 1,062 feet; range and energy not given.

EFFECTS.

The shell penetrated 15.6 inches of iron, broke up, the head remaining in the hole.

Tenth round.

Second round: Weight of shell, 2,000 pounds; powder charge, 400 pounds (Fassano); velocity, 1,499 feet.

EFFECTS.

The target was completely penetrated, a large portion of the plate was torn off, and the rear so ruined as to be incapable of repair.

Third round: Weight of shot, 2,000 pounds; powder charge, 264 pounds (English powder); velocity, 1,299 feet; range and energy not given.

EFFECTS.

The shell just passed through the plate, tore off a large piece, and split the plate from top to bottom. The backing was not pierced.

PENETRATION OF ARMOR—100-TON GUN (CHAMBERED).

First round. Fired at Spezzia June 23, 1879.

Weight of shot, 2,022 pounds (Gregorini chilled iron); powder charge, 550 pounds; initial velocity, 1,715 feet; initial energy, 41,241 foot-tons; energy per inch of shot's circumference, 739.57 foot-tons. Range not given; at former trials it was 100 yards.

DESCRIPTION OF TARGET.

The armor consisted of a steel plate 27.56 inches thick, manufactured by the Terre Noire iron works, and measured 9 feet by 4 feet 8 inches.

EFFECTS.

The shot penetrated the plate to a depth of 14 inches and rebounded, tearing off one-third of the plate.

Second round.

Weight of shot, 2,110 pounds (Whitworth compressed steel); powder charge, 550 pounds; initial velocity, 1,673 feet; initial energy, 40,966 foot-tons; energy per inch of shot's circumference, 734.65 foot-tons.

EFFECTS.

The shot pierced the armor and its backing, and, like the foregoing, tore off a third of the plate. The projectile itself was in no way deformed.

Third round.

Weight of shot, 1,946 pounds (Armstrong); powder charge, 550 pounds; initial velocity, 1,736 feet; initial energy, 40,653 foot-tons; energy per inch of shot's circumference, 729.07 foot-tons.

EFFECTS.

The projectile penetrated just 11.8 inches. The armor was punished severely by these three rounds, and although two out of three projectiles failed to pierce the plate, it was nevertheless rendered completely unserviceable.

THE 81-TON GUN. SHOEBURYNESS, 1877.

(Thickness of plates, 32 inches.)

PENETRATION OF ARMOR.

81-*ton gun* (*unchambered*). *Fired at Shoeburyness, February*, 1877.

Weight of shot, 1,700 pounds; powder charge, 370 pounds; range, 120 yards; initial velocity, 1,510 feet; striking velocity, 1,496 feet; total striking energy, 26,400 foot-tons; striking energy per inch of shot's circumference, 525 foot-tons.

DESCRIPTION OF TARGET (NO. 41).

The target consisted of four 8-inch plates (Brown), 16 feet long, 10 feet high, secured together in pairs by 3 bolts. The front plate was bolted to the second, the second to the third, the third to the fourth, and the fourth to the horizontal beams in the rear, with 5 inches of teak between the plates.

Total thickness of iron, 32 inches.

Total thickness of teak, 15 inches.

EFFECTS.

(Figs. 12, 14.)

The shot was fired at an angle of about $1\frac{1}{2}°$ from the perpendicular, and turned a little more in penetrating the target, so that its final inclination was about $2\frac{1}{2}°$ to the left and also about 2° downward The point of the projectile actually penetrated about 25 inches of iron, the head remaining entire in the hole and immovable, and about 11 inches of the rear part of the body broke up in the hole.

Shot penetrated, therefore, 25 inches of iron and 15 inches of teak. ("Engineering," Vol. XXIII, p. 378, gives penetration into iron, 25.5 inches.)

81-TON GUN (CHAMBERED).

Fired at Shoeburyness.

Weight of shot, 1,700 pounds; powder charge, 425 pounds; range, 120 yards; initial velocity, 1,600 feet; striking velocity, 1,585 feet; total striking energy, 29,615 foot-tons; striking energy per inch of shot's circumference, 589.2 foot-tons.

The target was the same as in preceding round.

EFFECTS.

(Figs. 12, 13, 14.)

The shell penetrated about 26 inches of iron and 15 inches of teak; but the total penetration, measured from the face of the target, is 7.4 inches more than in the foregoing round, the difference being accounted for by the greater amount of bulge in the rear. The point of the shot was visible through large cracks in the back of the target, in some places open to a width of 2½ inches. There was about 5 inches of iron still in advance of the point, but this was fissured and opened in a star crack. The rear plate was bulged or bent back nearly 14 inches.

THE 38-TON GUN. SHOEBURYNESS, 1876, 1877.

(Thickness of plates, 19½ inches, 26 inches.)

PENETRATION OF ARMOR.

38-ton Woolwich gun, caliber 12.5 inches (unchambered). Fired at Shoeburyness, 1876.

Weight of shot, 800 pounds (Palliser shell); powder charge, 130 pounds; range, 70 yards; striking velocity, 1,421 feet; striking energy, 11,210 foot-tons; energy per inch of shot's circumference, 285.4 foot-tons.

DESCRIPTION OF TARGET (NO. 40).

The target consisted of three 6½-inch wrought-iron plates, with 5 inches of teak between each pair. They measured 10 feet in length and 8 feet in width, and were secured to a timber structure. Total iron thickness, 19½ inches; teak, 10 inches.

NOTE.—A projectile of the 38-ton gun nearly penetrated an armored target of the following combination, viz: A 12-inch plate, an 8-inch plate, 6 inches of teak, and a 5-inch plate, into which last it penetrated 2 inches, or, altogether, 22 inches of iron and 6 inches of teak.

EFFECTS.

The projectile made clean holes, 12½ inches in diameter, through the front and middle plates, and formed a hole of the same diameter part of the way through the rear plate, knocking off the back moulds of this plate to a depth of 4 inches, the area of injured surface in rear measuring 2 feet 4 inches by 2 feet 3 inches.

The head of the shell was picked up in rear in an entire state, the point being uninjured and the form of the head unaltered. The main part of the body, which also passed through the target, was found broken into a few large pieces.

38-TON WOOLWICH GUN, CALIBER 12.5 INCHES (CHAMBERED).

Fired at Shoeburyness, March, 1877.

Weight of shot, 800 pounds; powder charge, 200 pounds; range, 70 yards; striking velocity, 1,525 feet; striking energy, 13,080 foot-tons; energy per inch of shot's circumference, 333 foot-tons.

DESCRIPTION OF TARGET.

The target fired at in the foregoing round was strengthened by the addition of a fourth 6½-inch plate in front, with 5 inches of teak between it and the one behind it, being the same thickness as in the intervals between the other plates. The target now contained 26 inches of iron and 15 inches of teak.

EFFECTS.

(Figs. 15, 16, 17.)

The shell, on entering the front plate, felt the least resistance to be on its proper right side, and therefore turned in that direction about 5° from the perpendicular. It penetrated the target till its point got something less than an inch into the back plate.

18-TON AND 25-TON GUNS. SPEZZIA, 1876.

(Thickness of plates, 22 inches.)

PENETRATION OF ARMOR.

18-*ton* (10-*inch*) *gun*. 25-*ton* (11-*inch*) *gun*. *Fired at Spezzia*, 1876.

18-*ton gun*.—Weight of shot, 397 pounds (Palliser shell); powder charge, 77.2 pounds; range, 100 yards; striking velocity, from 1,388 feet to 1,398 feet; striking energy, from 5,269 to 5,537 foot-tons.

25-*ton gun*.—Weight of shot, 531 pounds (Palliser shell); powder charge, 94.6 pounds; striking velocity, 1,260 feet; striking energy, 5,677 foot-tons.

DESCRIPTION OF TARGET.

Schneider steel plate. Thickness of solid plate, 22 inches; 28.8 inches wooden backing, in rear of which came two thin iron plates, together 1½ inches thick, the whole backed by a ship's frame.

EFFECTS.

(Fig. 2.)

The shot of the 18-ton gun struck the plate near the center and penetrated about 10 inches. At first the plate appeared to be but little damaged, but shortly after it split in two cracks, one running from the hole to the edge of the target, the other

extending some distance, but not to the edge of the plate. The shell was shattered into fragments.

(Fig. 4.)

A salvo from the 18-ton and 25-ton guns, fired next, dislodged a large piece from the right-hand top corner of the plate. The cracks already made were opened much wider and fresh cracks were visible. The entire plate, in fact, had suffered very severely and was far on the way to destruction.

Cammell wrought-iron plate.—Thickness of solid plate, 22 inches; 28.8 inches wooden backing, 1½ inches iron skin, the whole backed by a ship's frame.

EFFECTS.

(Fig. 1.)

The 18-ton gun fired one round, the shot penetrating about 10.8 inches Two cracks were developed, extending from a bolt-hole on left hand of target to the edge.

(Fig. 3.)

The next round was a salvo from the 18-ton and 25-ton guns.

The 10-inch shot struck near the edge of the plate upon a bolt, which was driven in, and a penetration of 18 inches was effected.

The 11-inch shot penetrated 13 inches and broke up.

The top layer of teak was lifted above the target edge; the entire plate was driven back one inch, a crack was made which extended from a bolt-hole to edge of plate, and the frame at the back was much shaken.

Marrel wrought-iron plate.—Thickness of solid plate, 22 inches; 28.8 inches wooden backing, 1½ inches iron skin, the whole backed by a ship's frame.

EFFECTS.

(Fig 1.)

The 18-ton gun fired one round, shot penetrating about 11 inches, opening a crack from lower left-hand bolt-hole.

(Fig. 3.)

A salvo from 18-ton and 25-ton guns dislodged a huge mass of iron, and a crack was formed extending from a bolt-hole towards the top edge of plate.

The shots penetrated 12½ and 14½ inches.

Cammell wrought-iron sandwich target.—Thickness of front plate, 12 inches; rear plate, 10 inches, with 12 inches of wood between plates and 16 inches wooden backing, 1½ inches iron skin, the whole supported by a ship's frame.

EFFECTS.

(Fig. 6.)

First round, 18-ton gun; shot penetrated 13 inches from the face of the target. Iron penetration, 12 inches.

(Fig. 8.)

The second round was a salvo from the 18-ton and 25-ton guns. Both projectiles pierced the front plate and penetrated 2.4 inches into the rear plate, dislodging the right-hand corner of plate.

Marrel wrought-iron sandwich target.—Thickness of front plate, 12 inches; rear plate, 10 inches, with 12 inches of wood between plates and 16 inches wooden backing, 1½ inches iron skin, the whole backed by a ship's frame. The construction of this target was the same as Cammell's sandwich target.

EFFECTS.

(Fig. 5.)

The shot of the 18-ton gun penetrated only 10 inches into the front plate, but split it in several directions, some pieces being nearly detached.

(Fig. 7.)

The next round was a salvo from the 18-ton and 25-ton guns. The 10-inch shot pierced the front plate and penetrated 1 inch into the wood.

The 11-inch shot, after going through front plate, penetrated the rear plate to a depth of 2 inches.

The front plate was much cracked and pieces of it were quite detached, and wide fissures opened.

PENETRATION OF ARMOR.—24 CENTIMETERS (9.45 INCHES) KRUPP GUN, FIRED AT MEPPEN, 1879.

DESCRIPTION OF TARGET.

The target consisted of two wrought-iron plates; front plate, 12 inches thick; rear plate, 8 inches, with 2 inches of wood between them; the whole supported by heavy timber. Total thickness of iron, 20 inches.

First round.—Weight of shot, 348 pounds (Krupp steel shell, 2.8 caliber); powder charge, 165 pounds; initial velocity, 1,901 feet; striking velocity, 1,876 feet; striking energy, 8,508 foot-tons; striking energy per inch of shot's circumference, 286.6 foot-tons; range, 492 feet.

EFFECTS.

(Figs. 18, 19.)

The projectile pierced the target and went 7,218 feet beyond. The plate showed a crack about 19 inches long and .08 inch wide.

The shell was shortened .6 inch, but otherwise remained intact.

Second round.—Weight of shot, 347 pounds (Krupp steel shell, 2.8 caliber); powder charge, 165 pounds; initial velocity, 1,876 feet; striking velocity, 1,852 feet; striking energy, 8,243.6 foot-tons; striking energy per inch of shot's circumference, 277.6 foot-tons; range, 492 feet.

EFFECTS.

(Figs. 18, 20.)

The shell passed through target and went 3,937 feet beyond. It produced 3 cracks, one in the upper portion 27½ inches long, on the average 1½ inches wide, extending to the edge of the plate. The other two cracks were in the lower part of the plate, extending to the right and left, one about 23 inches long and .08 inch wide.

The shell, when recovered, was found to be shortened about .8 inch, but otherwise intact.

COMPOUND ARMOR TRIALS.

At Portsmouth: 1877, 1878, 1879, 1880, 1882. Gun, 9-inch (12-ton); gun, 10-inch. Thickness of plates, 9 inches, 10.6 inches, 11 inches.

At Shoeburyness: 1877, 1879, 1880. Gun, 7-inch; gun, 9-inch (12-ton); gun, 12.5-inch (38-ton). Thickness of plates, 5 inches, 9 inches, 10 inches, 18 inches.

At Gâvres, France: 1880. Gun, 32 centimeters (12.6-inch). Thickness of plates, 15.75 inches, 19.68 inches.

REFERENCES.—"Engineering," Vols. XXIV, XXV; "The British Navy," Vols. I and II, by Sir Thomas Brassey; "Revue Maritime et Coloniale," December, 1880, May, 1881, October, 1881; "Army and Navy Journal," September 9, 1882; "Ordnance Notes," No. 205.

COMPOUND ARMOR.

Trials at Portsmouth, in 1877, on board the target-ship Nettle.

Gun, 12-ton (9-inch) M. L. Woolwich R.—Weight of shell (Palliser), 250 pounds; powder charge, 50 pounds; initial velocity, 1,420 feet; initial energy, 3,496 foot-tons; initial energy per inch of shot's circumference, 123.6 foot-tons; range, 30 feet.

Three shots, forming a triangular diagram, were to be fired at each plate, the points of impact being about 2 feet apart. The line of fire was normal to the face of the targets.

The targets were held by 2½-inch steel bolts to a strong timber backing.

In order to have a basis of comparison, a solid wrought-iron plate, made by Messrs. Cammell, was fired at first.

This plate was 9 feet 9 inches wide, 7 feet 9 inches high, and 9 inches thick.

The first shot fired penetrated the plate; the other two failed to penetrate it, but the plate was bulged in the rear considerably.

DESCRIPTION OF TARGETS.

First target consisted of a compressed steel plate, 9 inches thick, made by Sir Joseph Whitworth. It measured 6 feet 8 inches in width by 6 feet in height.

The plate had fifty hardened screw plugs inserted so close to each other that a projectile could not do more than slightly penetrate the plate without coming in contact with some of the plugs. Sir Joseph thus claims to obtain a maximum strength with reduced thickness of armor.

The steel plate had a tensile strength of about 40 tons per square inch; the plugs, about 100 tons per square inch.

EFFECTS.

First round.—Shot penetrated 4.1 inches.

Second round.—Shot penetrated 2.85 inches.

Third round.—Shot broke up, head remaining in plate. Penetration not ascertained.

The plate resisted the shot well, but was much starred for lack of oil toughening.

The plugs successfully performed their allotted task of breaking up the projectile, but they also appeared to assist in cracking the plate.

Second target was made of sub-carburized steel by Messrs. Cammell. The plate measured 9 feet 9 inches in width, 7 feet 9 inches in height, and 9 inches in thickness. It was a solid steel plate, in which the carbon was so low, being reduced to .13 per cent., that the metal approached in character to wrought iron. The object in view in producing this metal was to obtain a steel plate which should offer a greater resistance than iron to penetration, and yet not star under impact.

EFFECTS.

The plate did not star, but it split; each successive round further developing the cracks. The steel was of very high quality, and the plate came out from the ordeal remarkably well.

Third target was a combined iron and steel plate, made under the patent process of Mr. Alexander Wilson, which consists in heating the iron plate, in a specially constructed furnace, to a certain degree of redness, and, while in the furnace, in pouring upon it the molten steel to the required thickness.

The steel has a much higher temperature than the iron plate, that of the latter being comparatively low. The excess of heat in the steel beyond the welding temperature of the iron serves to bring up the surface of the iron to a welding heat. The carbon in the steel carburizes the iron to a depth of from one-eighth to three-sixteenths of an inch, thus forming a zone of mild steel between the hard steel and the iron, which constitutes an inseparable weld.

The ~~same~~ *small* plate, which was tried at Shoeburyness, gave remarkably good results.

The steel is produced by Siemens' process.

The plate tried consisted of a steel face, 4 inches thick, containing .64 per cent. of carbon, followed by 5 inches of wrought iron, and measured 9 feet 9 inches in width, 7 feet 1½ inches in height, and 9 inches in thickness.

EFFECTS.

First round.—The shot effected a complete penetration, and was estimated to have gone about 15 inches into the wooden backing.

Second round.—The shot went through and about 9 inches into the backing.

Third round.—Was not fired.

The plate showed marked signs of defective welding, and there were appearances of burning in the metal. It was therefore concluded that this system was not fairly represented.

Fourth target was a sandwich steel and iron plate, 8 feet wide, 5 feet 11 inches high, and consisted of a face plate of iron three-fourths of an inch thick, a central plate of steel 6½ inches thick, and a back plate of iron 1¾ inches thick. The steel contained .57 per cent. of carbon and was considered hard.

Total thickness of metal, 9 inches.

EFFECTS.

The penetration at the first round was 6.75 inches; the second round produced a long crack; while the third round punished the plate severely.

Here, again, imperfect manufacture was apparent, the result, as before, of the manufacturer having been overtasked in having to produce the plates to the order of the government within a comparatively limited period.

Trials at Portsmouth, in 1878, on board the target-ship Nettle.

The conditions under which these trials were made were similar to those in the previous experiments, except that in the last the projectiles were said to be of somewhat harder character, and were also fitted with gas-checks, which gave a higher terminal velocity and rendered the ordeal somewhat more severe.

The three shots on each plate were delivered at three marked points, 2 feet apart, and forming a triangle with the apex downwards, the second shot in each case being delivered at the apex.

DESCRIPTION OF TARGETS.

Target No. 1 consisted of equal thicknesses of steel and wrought iron, having a face of low steel 4½ inches thick, welded upon a backing of iron 4½ inches thick. The plate was made under the patent process of Mr. J. D. Ellis, which consists in attaching the steel to the iron plate after it has been heated in the furnace.

Mr. Ellis produces his steel by the Bessemer process.

The plate measured 7 feet 9 inches by 6 feet 8 inches, 9 inches thick, and was secured by navy bolts to timber backing.

EFFECTS.

The first shot cracked the plate from the point of impact to the apex of the triangle, while the second caused a continuation of the crack to the bottom of the plate, which penetrated through the target. Other cracks did not extend beyond the steel.

The projectiles, which all broke up on impact, each caused a bulge of 3 inches to the rear of the iron plate, and no cracks were developed except at the points of impact.

The weld between the metals was perfect.

Target No. 2.—The plate consisted of equal thicknesses of steel and wrought iron, having in this case a face of harder steel, 4½ inches thick, welded upon a backing of iron 4½ inches thick, the welding process being the same as in the foregoing plate.

The plate measured 7 feet 6 inches by 6 feet 7 inches, 9 inches thick, and was secured by navy bolts to a timber backing.

EFFECTS.

The plate, under the impact of the projectile, cracked and starred in all directions; the third shot, which struck a bolt, caused a large portion of the plate, about one-third, to become detached.

The projectiles were broken up into small fragments, but they had punished the plate severely, both steel and iron being cracked through.

Trials at Portsmouth, in 1879, *on board the target-ship Nettle.*

Gun, 12-*ton* (9-*inch*) *M. L. Woolwich R.*—Weight of shot, 251 pounds (Palliser); powder charge, 50 pounds; initial velocity, 1,420 feet; range, 30 feet.

The conditions under which these trials were made were similar to those already mentioned.

DESCRIPTION OF TARGET.

The plate was manufactured by Messrs. Cammell & Co., and consisted of a steel face 3½ inches thick and 5½ inches of iron; total thickness of metal, 9 inches. It measured 7 feet by 8 feet, and represented a section of the armor intended for the turret of the Inflexible.

EFFECTS.

The first shot struck the armor at the center; the point of projectile remained fixed in the plate; the body broke up. The heads of the other two shots indented the plate to the same depth, while their bodies were shattered into small fragments. The face of the plate showed a number of fine superficial cracks after the first round, which were enlarged by succeeding shots, but the armor still remained serviceable.

Trials at Portsmouth, September 28, 1880, *on board the target-ship Nettle.*

Gun, 12-*ton* (9-*inch*) *M. L. R.*—Weight of shot, 270 pounds (Palliser shell, with gas-check); powder charge, 50 pounds; velocity, 1,406 feet; range, 30 feet.

The conditions under which these trials were made were similar to those already mentioned.

DESCRIPTION OF TARGET.

The plate was made by Messrs. Cammell, and measured 6 feet 3 inches by 7 feet, having a total thickness of 11 inches, of which 3 inches were cast steel.

EFFECTS.

None of the three shots pierced the plate; one projectile penetrated 6 inches and remained fixed in the plate; the other two broke up into small fragments.

DESCRIPTION OF TARGET.

The plate was made by the Ellis process, and measured 7 feet 10½ inches by 5 feet 5 inches. Thickness of metal, 10.6 inches, of which 3.54 inches were steel, the rest iron.

EFFECTS.

The first shell made an indent of 4.92 inches; the second, 4.82 inches; and the third, 5.51 inches. The heads of the first two shells remained fixed in the plate until the shock of the third knocked them out.

The shells, with the exception of the heads, were broken into numerous fragments. The first and third rounds produced but slight cracks, while the effects of the

second round were more serious; but the full extent of the damage to the plate could not be ascertained, as the frame and backing obstructed the view.

Trials at Portsmouth, July, 1882, on board the target-ship Nettle.

Gun, 10-inch.—Weight of shot, 400 pounds; powder charge, 70 pounds; range, 30 feet. Velocity and energy not stated, but former firing gave initial velocity, 1,364 feet; total initial energy, 5,165 foot-tons; energy per inch of shot's circumference, 164.4 foot-tons.

DESCRIPTION OF TARGET.

The armor-plate was manufactured by Sir John Brown & Co., on the Ellis principle, and measured 7 feet 9 inches by 5 feet 10½ inches, 11 inches thick.

It had previously been fired at with a 9 inch gun, under the usual conditions, viz: 50 pounds powder, 250 pounds chilled shell; range, 30 feet. The first shot had produced the small indent of 3.7 inches without any crack, while the second and third rounds produced indents of 4.4 inches and 3.9 inches, respectively, and several cracks, one of which extended to the edge of the plate.

EFFECTS.

The first shot was fired at the right bottom corner, 2 feet from each edge, and produced a clearly defined indent of 4.4 inches and several cracks circumferential to the point of impact, one of which reached to the bottom edge and extended through the plate.

The second shot was directed against the left bottom corner, 19 inches from the side and 23 inches from the lower edge, while the third fell at the right top corner, 19 inches from the top edge and 2 feet from the side.

Owing to the points of the shell remaining fixed in the plate, the depth of the indents could not be measured.

The bulges at the back varied from three-eighths to seven-eighths of an inch in height, and were not opened out.

Considering the severity of the second test, and that there was hardly room left for another shot, the damage effected was slight, and the plate would still have afforded efficient protection.

The heavier gun seems to have slightly pushed in the entire surface of the plate within certain areas, defined by various injuries, but without showing any increased penetration.

COMPOUND ARMOR.

Trials at Shoeburyness, 1877.

Gun, 7-inch.—Weight of shot, 113 pounds; powder charge, 30 pounds; range, 30 yards; velocity, not given.

DESCRIPTION OF TARGETS.

Target No. 1 was a hammered plate with a 5-inch face of hard steel, containing .64 per cent. of carbon, welded upon 4 inches of wrought iron.

Total thickness of metal, 9 inches.

EFFECTS.

The projectile broke up in its head as well as in the body, the plate being scored all over its face by the flying fragments. The diameter of the shot mark was 9½ inches; the point of the shot had penetrated little more than 3 inches, whereas with the same energy in striking it would in a wrought-iron plate of the same thickness have reached to a distance of 12 inches from the face of the plate.

Target No. 2 was rolled, and consisted of 4½ inches of somewhat softer steel than the foregoing (containing .48 per cent. of carbon) and 4¾ inches of iron.

Total thickness of metal, 9 inches.

EFFECTS.

The shot indented the plate to a depth of nearly 5½ inches and broke up, but was not so thoroughly destroyed as in previous experiment.

Trial with a 9-inch (12-ton) gun.

Weight of shot.—First round, 268 pounds (Whitworth compressed steel shell); second round (Cammell cast-steel shell). Range, 50 yards.

No other data given

DESCRIPTION OF TARGET.

The plate measured 10 inches in thickness, of which 4 inches were steel and 6 inches of ordinary iron. The plate was unbacked and unsupported.

EFFECTS.

The Whitworth shell indented the plate to a depth of 10½ inches, producing a considerable crack at the back. Though the face was cracked, the steel adhered to the iron. The projectile was much set up.

The Cammell cast-steel shell went through the plate, the head being broken into three pieces and the body into several more. The steel face of the plate was more or less cracked, but still continued to adhere to the iron.

Trial with a 7-inch gun, Shoeburyness

Gun, 7-inch.—Weight of shot, 113 pounds; powder charge, first round, 8½ pounds; powder charge, second round, 25 pounds; range, 30 yards; velocities not given.

DESCRIPTION OF TARGET.

Two compound plates, manufactured by Messrs. Brown & Co., were tried. They were made by heating hard masses of Bessemer steel and wrought iron in an ordinary furnace and rolling them down to 5 inches in thickness, borax being used as a flux. The steel and iron were in equal parts, the former containing .5 per cent. of carbon. One plate was hardened and the other unhardened.

EFFECTS.

First round (8½ pounds powder).—The hardened plate was indented 3⅓ inches, or about half the depth of the usual indentation from the same blow on a rolled-iron plate of 5 inches.

Second round (25 pounds powder).—The shell just forced its point through the plate and broke up.

The unhardened plate offered a less satisfactory resistance.

In 1879 further experiments were carried out at Shoeburyness with 14-inch wrought-iron armor in comparison with 12-inch compound armor, both being unbacked.

The average penetration into five steel plates was about 6⅓ inches, and into eight iron plates 13⅓ inches.

Trial at Shoeburyness, 1880.

Gun, 38-ton (12½-inch).—Weight of shot, 828 pounds (Palliser); powder charge, 180 pounds; range, 227 feet; initial velocity, 1,516 feet; striking velocity, 1,504 feet; striking energy, 12,545 foot-tons.

DESCRIPTION OF TARGET.

The plate was manufactured by Messrs. Cammell & Co., was 18 inches in thickness and of large area. The face consisted of 5 inches of steel, united at the back to 13 inches of wrought iron, the entire mass constituting what is termed a steel-faced plate. It rested against a mass of timber without being fastened.

EFFECTS.

The projectile broke up on contact with the plate, driving part of the ogival head into the metal, and producing two horizontal cracks extending right and left from the spot where the shot struck. The crack on the left was scarcely continuous, but showed itself as far as the edge. The crack on the right was more pronounced, and probably went as far as the right edge, but this could not be seen, owing to the intervening supports.

There was no reason to suppose that either crack extended deeper than the steel, and consequently the plate on the whole may be said to have suffered but little.

On the other hand, a steel shell fired from the same gun against a 16-inch compound plate, with a striking energy of 12,547 foot-tons, broke the plate completely, the projectile itself breaking up

Trials at Gâvres, France, of the armor of the Terrible with the 32-centimeter (12.6-inch) gun.

No data given as to charge, range, and velocities.

(NOTE.—"The British Navy," Vol. II, pp. 106–'7, gives the following for a 32-centimeter gun: Weight of steel and chilled shot, 770 pounds; weight of common shot, 630 pounds; weight of powder, 132 pounds; initial velocity for steel shot, 1,394 feet; initial velocity for common shot, 1,496 feet; energy of steel shot, 10,390 foot-tons; energy of common shot, 9,730 foot-tons.)

DESCRIPTION OF PLATE.

The plate was manufactured by Schneider, of Creuzot, and weighed 18 tons. The upper part had a thickness of 19.68 inches and the lower part a thickness of 15.75 inches.

EFFECTS.

Three shots were fired against the plate at points which formed an equilateral triangle, the sides of which measured 31½ inches. The projectile in striking the plate broke up and produced but slight indents.

The first shot only caused three small cracks on the face of the plate; the two following rounds produced no new cracks. The examination of the rear face proved that the plate withstood the trial exceptionally well.

"Ordnance Notes" No. 205, p. 3, gives the following:

"The use of this compound armor plating is now extending in England, and in France also it has been used upon two great ships, in consequence of experiments made in March and April, 1880. In these experiments six different plates, of thickness varying from 15.75 inches to 19.68 inches, were tried; of these one was a compound of iron and steel, one was of iron, two of cast steel, and two of forged cast steel. They were subjected to the fire of a 32-centimeter (12.598-inch) gun at 288.7 feet distance.

"In the first round, with a chilled cast-iron projectile weighing 758 pounds and having an initial velocity of 1,473 feet, the compound plate was penetrated to a depth of 7.7 inches, one hard-steel plate 14.9 inches, one soft-steel plate 19.7 inches, the cast-steel plate 18.5 inches, and the wrought-iron plate 24 inches. A second projectile similar to the first, but having an initial velocity of 1,433.7 feet, penetrated 8.7 inches in the compound plate, 21.5 inches in the hard-steel plate, and passed through all the others. A third projectile of steel when fired against the compound plate rebounded from it."

GRUSON CHILLED IRON ARMOR TRIALS 1869, 1873, AND 1874.

(Plate III.)

Guns.—15-centimeter (6-inch) R.; 17-centimeter (6.7-inch) R.; 21-centimeter (8.27-inch) R.; 24-centimeter (9.45-inch) R.; 28-centimeter (11-inch) R.; 28-centimeter (11-inch) rifled mortar.

Thickness of armor.—21.62 inches, 28.3 inches, 31.5 inches, 35.4 inches.

Thickness of proof-plates.—7.8 to 11.8 inches, 9 to 10 inches.

REFERENCES.—Gruson's publications, "Gruson's Hartguss-Panzer," Berlin, 1878; "Mittheilungen des Ingenieur Comités," 22te Heft, 1877, by Major Kuster.

GRUSON'S CHILLED IRON ARMOR.

First trial in 1869.

(Maximum thickness of armor at embrasure, 28.3 inches.)

Gun, 15-centimeter (6-inch).—Fired three rounds, solid steel shot. Striking energy per round, 365 foot-tons.

EFFECTS.

All the shot broke up, producing no effect on the armor.

Gun, short 21-*centimeter* (8.27-*inch*).—Fired six rounds, of which three were solid steel and three chilled-iron shot. Striking energy per round from 1,560 to 1,876 foot-tons.

EFFECTS.

The rounds produced small indents, 0.25 to 0.37 inches deep, and two cracks 8 and 9½ inches long, .06 inch wide.

Gun, 24-*centimeter* (9.45-*inch*).—Fired four rounds, of which one was solid steel shot and three were chilled-iron shells. Striking energy per round from 3,048 to 3,080 foot-tons.

EFFECTS.

These four rounds produced two fine cracks near the embrasure and indents three-eighths inch deep.

Gun, long 21-*centimeter* (8.27-*inch*).—Fired seven rounds, four of which were chilled-iron shells and three chilled-iron shot. Striking energy per round from 2,706 to 2,716 foot-tons.

EFFECTS.

These rounds produced new cracks and lengthened existing cracks. A piece of the armor was knocked off.

The total number of rounds fired against the armor were twenty, ten of which were solid steel and chilled-iron shot, striking a surface a little over 18 inches square with a total energy of 26,675 foot-tons. All the projectiles broke up on impact.

Trial of an embrasure plate; maximum thickness 31.5 *inches. December,* 1873.

Gun, 28-*centimeter* (11-*inch*).—Fired three rounds with blind chilled-iron shell. Energy per round, 5,683 foot-tons.

EFFECTS.

The three projectiles hit the armor in nearly the same place, about 9 inches from the cheek of the embrasure.

The first round produced a flat indent, slightly starred; the second two fine cracks about .07 inch wide, one of which was visible in the rear; while the third round produced some more fine cracks.

Trial of an embrasure plate, 5 *feet* 8 *inches square; maximum thickness* 21½ *inches. May,* 1874.

Gun, 15-*centimeter* (6-*inch*).—Fired 193 rounds loaded common shell. Energy per round, 612 foot-tons. Ten rounds loaded chilled-iron shell. Energy per round, 706 foot-tons.

EFFECTS.

The first thirty-two rounds had no effect on the plate. The thirty-third round caused a slight indent 2 inches wide, which slowly increased with succeeding rounds, but was confined to the surface of the plate. After the seventieth round a fine crack appeared, extending from the point of impact towards the interior of the embrasure, but which did not increase with succeeding rounds.

Gun, 17-centimeter (6.7-inch).—Fired twenty rounds loaded chilled-iron shell. Energy per round, 1,478 foot-tons.

EFFECTS.

The sixth round produced the first effect, consisting of a fine crack 10¼ inches long, which increased in length with subsequent rounds, extending towards the upper and lower edge of the plate. The eighth round broke off the left corner of the plate, while the next twelve rounds produced only additional fine cracks and slight abrasions.

Gun, 15-centimeter (6-inch).—Fired 65 rounds loaded chilled shell. Energy per round, 706 foot-tons.

EFFECTS.

The eleventh round of this series produced a crack between the two embrasures, other cracks appearing during subsequent firings, some of them one-quarter inch wide. The face of the armor showed abrasions 3 inches deep.

There were fired against this armor in all two hundred and eighty-eight rounds, with a total energy of 200,553 foot-tons.

After the firing the armor was still considered serviceable.

Trial of a Roof plate 7.8 to 11.8 inches thick

Gun, 28-centimeter (11-inch) rifled mortar.—Range, 2,913 feet; elevation, about 30°; energy per round, 3,760 foot-tons.

Forty-five rounds common blind shell were fired, of which five hit the plate.

EFFECTS.

The plate was punished severely, completely cracked through, and separated into five different pieces, which were ready to fall.

Trial of an embrasure plate; maximum thickness, 35.4 inches. July and August, 1874.

Gun, 28-centimeter (11-inch).—Fired nineteen rounds blind chilled-iron shell. Energy per round, 5,683 foot-tons.

EFFECTS.

(Fig. 21.)

On account of the curvature of the plate, the projectiles struck the armor at angles varying from 20° to 90° to the face.

The first two rounds produced no visible effects; the third cracked the plate from the upper part of the embrasure to the top of the plate, the crack being visible in the rear. The fourth round, striking the plate below the embrasure, produced a crack

which extended from the sole of the embrasure to the bottom of the plate, thereby separating the plate into two parts. The fifth round caused another crack, while the sixth and seventh produced no visible damage. After the eighth round another small crack appeared, while the ninth and tenth rounds left no effect. After these ten rounds had been fired the face of the armor showed indents ranging from $2\frac{1}{3}$ to 5 inches deep, while on the rear face three distinct cracks were noticed extending from the center of the embrasure to the top and bottom of the plate and to the right, whereby the right upper quadrant of the armor became detached, though still remaining in position; on the left half of the plate another fine crack had appeared.

The eleventh round caused a crack which extended from the point of impact to the bottom of the plate.

The twelfth round increased already existing cracks and damaged considerably the roof covering.

The thirteenth round knocked down a portion of the roof covering and pressed also the right upper quadrant of the armor slightly to the rear. With this and the succeeding rounds a gradual disintegration of the armor took place. The effects of the firing were marked by additional cracks appearing on the rear face, principally around the embrasure, while the face of the armor showed large indents and abrasions.

The sixteenth round knocked off a small piece of the edge of the adjoining pillar plate.

The next three and last rounds caused but slight changes in the condition of the armor, which was now divided into four parts, of which one, namely the right upper quadrant, had only been disturbed, having been pressed back from its original position about 3 inches.

The rear face of the armor showed a network of cracks with slight abrasions along their edges.

The front face of the right lower quadrant exhibited a surface about 6 feet square, abraded and indented to a depth of 3 inches.

The general form of the armor remained unchanged, and although divided into four pieces, it still held together and was considered in a serviceable condition; yet it was apparent that a few more rounds would demolish it.

Trial of a roof plate 9 to 10 inches thick.

Gun, 28-centimeter (11-inch) R.—Fired five rounds blind chilled-iron shell. Striking energy, 7,450 foot-tons, normal to the plate. Angle of fall, 20°.

EFFECTS.

The first two shots made only slight indents and starred the surface; the third round produced larger cracks, which extended to the edge of the plate. The fourth shot cracked the plate into two parts. The fifth round added no new cracks, but it widened and lengthened the existing ones, also knocking down a piece of the armor.

Although severely punished, the roof plate was yet considered serviceable.

TRIAL OF COMPOUND AND STEEL ARMOR PLATES, AT SPEZZIA, NOVEMBER 16–21, 1882.

(Plate II.)

The Italian authorities, having adopted for the towers of the Italia and Lepanto plates 18.9 inches thick, tested the trial plates furnished for that purpose by the manufacturing firms of Sir John Brown & Co. and Cammell & Co., of England, and Schneider, of France, at Spezzia, in November, 1882. The gun used in making the tests was the muzzle-loading 100-ton Armstrong rifle.

TRIAL OF CAMMELL'S PLATE.

(Figs. 1, 2, 3, 10.)

This plate consisted of a wrought-iron foundation plate, with a steel face applied by Wilson's patent method, the steel being run on the face of the wrought iron and the whole rolled down from a thickness of about 30 to 18.9 inches. The steel, extending to a depth of about 6 inches in the finished plate, contained about 0.65 per cent of carbon. The plate measured 18.9 inches in thickness, 10 feet 10 inches in length, and 8 feet 7 inches in height, and weighed nearly 31½ tons. The plate was fastened to the backing by six bolts; diameter of bolt-holes, 4½ inches. The backing and supports were the same in all three targets. Each plate was set in an iron frame made of three thicknesses of strips of 6-inch armor, the width of the frame being about 33 inches and the thickness about 18 inches. These were bolted to the backing, which consisted of four layers of oak balks, each layer 1 foot thick.

First round.—Weight of shot, 2,000 pounds (Gregorini chilled iron); powder charge, 328.5 pounds (Fassano); striking velocity, 1,219 feet; total striking energy, 20,600 foot-tons; striking energy per inch of shot's circumference, 371.7 foot-tons.

EFFECTS.

(Fig. 4.)

The shot cracked the plate completely through; width of crack from 0.6 to 1 inch. Several fine hair cracks were developed. The shot itself broke up, the head remaining in the plate. No indentations on the plate were made by the fragments of the shot, and the face of the plate remained flat, that is, free from bending. The iron frame had yielded outwards from 4 to 6 inches near the point of impact, and a number of bolt-heads in front were broken and some cut by shot, fragments, &c. The whole plate was set back 3 inches at the end struck. In rear one large plate bolt was broken and several small backing and frame bolts.

Second round.—Weight of shot, 2,000 pounds (Gregorini chilled iron); powder charge, 478 pounds; initial velocity (479.4 meters), 1,572.8 feet; striking velocity, 1,565 feet; total striking energy, 33,960 foot-tons; striking energy per inch of shot's circumference, 613.0 foot-tons.

EFFECTS.

(Figs. 14, 15.)

The shot did not penetrate the armor, but broke it, bringing down the whole plate. All the bolts were drawn or snapped. One beam in the rear was broken, others started and split. The plate was bulged at the back opposite the point of impact.

Trial of Brown's plate.

(Figs. 1, 2, 3, 10.)

This plate differs from Cammell's in having a thin rolled steel face plate of about 3 inches thick attached to the wrought-iron foundation plate by molten steel, in place of allowing the molten steel itself to form the face. This is what is known as Ellis's patent. The total thickness of steel was about 6 inches, containing about 0.7 per cent. of carbon. Thickness of plate, 18.9 inches; length, 10 feet 10 inches; height, 8 feet 7 inches. Six bolts held the plate to the backing. Iron frame and backing the same as in Cammell's plate.

First round.—Weight of shot, 2,000 pounds (Gregorini chilled iron); powder charge, 328.5 pounds; striking velocity, 1,222 feet; total striking energy, 20,710 foot-tons; striking energy per inch of shot's circumference, 373.8 foot-tons.

EFFECTS.

(Fig. 6.)

The shot on striking the plate broke up, leaving a small portion of the head in the plate, projecting about 2½ inches, the indent being apparently but slight. The plate showed a narrow, long crack and some hair cracks. The plate had bodily moved back about 2 inches, and at right bottom—the corner struck—about 4 inches. The face appeared slightly concave in the region of the point of impact. At the rear some small frame and backing bolts had snapped, but no large plate bolts.

Second round.—Weight of shot, 2,000 pounds (Gregorini chilled iron); powder charge, 478 pounds; initial velocity (478 meters), 1,568 feet; striking velocity, 1,564 feet; total striking energy, 33,910 foot-tons; energy per inch of shot's circumference, 612.0 foot-tons.

EFFECTS.

(Figs. 12, 13.)

The projectile split the plate into six main fragments, all of which were dislodged except one, which remained supported by two bolts. The shot apparently had not penetrated to any great depth, but had broken the plate. The head of the shot had detached itself. The wood backing in the center was split and torn; the side frame pieces were thrown outwards at the bottom ends. At the back two beams were badly broken and forced back, besides many bolts were dislodged. The plate bolts were snapped or drawn with the exception of the two which held up the piece of armor plate.

Schneider's steel plate.

(Figs. 1, 2, 3, 11.)

Schneider's (Creusot Company) plate consisted wholly of steel, made with 0.45 per cent. of carbon. The face was chilled by lowering it to a depth of 6 inches in oil. The plate was hammered from a thickness of 7 feet down to 18.9 inches. It was

secured by 20 screw bolts, each 4½ inches in diameter, screwed into the back of the plate to a depth of 2¾ inches. Length of plate, 10 feet 10 inches; height, 8 feet 7 inches. The frame and backing were the same as in the foregoing plates.

First round.—Weight of shot, 2,000 pounds (Gregorini chilled iron); powder charge, 328.5 pounds; striking velocity, 1,232 feet; total striking energy, 21,050 foot-tons; striking energy per inch of shot's circumference, 379.8 foot-tons.

EFFECTS.

(Fig. 5.)

The plate resisted admirably, showing no cracks at all. The shot broke up, a large fragment of the head remaining in the plate and projecting about 6½ inches, the plate being slightly raised or bulged in the surrounding region. The rear portion of the projectile was broken up into small pieces. The iron frame was started, opening about 5 inches near point of impact. At the back several small backing bolts and bolt heads were snapped off, but none of the large plate bolts.

Second round.—Weight of shot, 2,000 pounds (Gregorini chilled iron); powder charge, 478.3 pounds; striking velocity, 1,545 feet; total striking energy, 33,100 foot-tons; striking energy per inch of shot's circumference, 605 foot-tons.

EFFECTS.

(Fig. 7.)

The shot indented the plate 8¼ inches, the portion adhering measuring about 18 inches across. The plate split vertically across and continued to crackle for many minutes, cracks forming and opening until the main fissure was about 0.9 inch wide near the bottom and 0.7 inch wide a little above the point of impact. The whole target was heated for about a foot around the edge of the shot. Hair cracks were opened apparently extending to a considerable depth, a very small one on the left edge visibly extending completely through the plate. The side frames were sprung wider open on the left. From the shot hole of first round two new hair cracks were started by this round. The back of the target stood well; some small bolts were detached and frames cracked, but no plate bolts were visibly injured.

Third round.—Weight of shot, 2,078 pounds; powder charge, 478 pounds; initial velocity, (471.4 meters), 1,546.5 feet; striking velocity, 1,538 feet; total striking energy, 34,080 foot-tons; striking energy per inch of shot's circumference, 615.1 foot-tons

EFFECTS.

(Figs. 19, 24.)

The shot struck the upper right-hand portion of the plate, breaking up that portion of the armor struck and driving fragments of it into the backing and to the right. The right-hand frame was thrown aside and left hanging by its bolts, nearly drawn. The top frame was thrown to the front, so as to hang over the face of the target. A part of the plate was brought down by the shot, which rebounded and lay in front. This

shot was set up and the extreme point broken off. The original length of the shot was about 44½ inches; it was set up to a length of 28 inches. The wood backing was rent and split, as seen from the front of the target. At the back seven horizontal beams were broken and split, and some of the upper tiers of beams were lifted with the top frame One large plate bolt was driven far out. The entire portion of backing beams projected about 4 feet.

Fourth round.—Weight of shot, 2,124 pounds (cast-steel Italian projectile); powder charge, 478 pounds; striking velocity, 1,512 feet; total striking energy, 33,670 foot-tons; striking energy per inch of shot's circumference, 607.7 foot-tons.

EFFECTS.

(Figs. 25, 26.)

The shot struck the plate close to the edge of the left top portion, driving it over and burying itself in the backing, rendering the whole structure a wreck. The top frame was dislodged and fell down; the backing was utterly destroyed. The shot was broken, but the fracture and appearance of the head was very good. Only a portion of the plate, however, was dislodged, and no one of the four shots got through the target.

TABLE OF VELOCITIES, IN FEET PER SECOND.

[Computed by Krupp's Ballistic Tables.]

Guns.	Cal.	Weight of—		Ranges, in yards.															
		Powder.	Shot.	At muzzle.	600	1,200	1,800	2,400	3,000	3,600	4,200	4,800	5,400	6,000	6,600	7,200	7,800	8,400	9,000
	Inch.	Lbs.	Lbs.																
100-ton Armstrong, chambered	17.75	550	2,022	1,715	1,653	1,592	1,535	1,479	1,424	1,372	1,323	1,276	1,232	1,191	1,156	1,123	1,093	1,066	1,040
100-ton Armstrong, chambered	17.75	776	2,000	1,832	1,765	1,699	1,637	1,577	1,518	1,462	1,408	1,355	1,305	1,259					
81-ton Woolwich, chambered	16	445	1,760	1,657	1,601	1,546	1,494	1,443	1,393	1,346	1,300	1,258	1,218	1,181					
38-ton Woolwich, chambered	12.5	200	800	1,590	1,518	1,449	1,383	1,322	1,266	1,213	1,166	1,125	1,089	1,058					
71-ton (40-centimeter) Krupp, chambered.	15.75	485	1,715	1,703	1,646	1,590	1,536	1,484	1,434	1,385	1,338	1,293	1,251	1,211					
51-ton (35.5-centim'r) Krupp, chambered.	14	298	1,146	1,645	1,580	1,517	1,457	1,399	1,344	1,292	1,244	1,198	1,159	1,124					
18-ton (24-centimeter) Krupp, chambered.	9.45	165	474	1,688	1,614	1,544	1,477	1,412	1,351	1,294	1,241	1,192	1,149	1,113					
8-inch converted U.S. R., unchambered	8	35	180	1,450	1,335	1,234	1,152	1,088	1,036	990	948	910	874	840					

TABLE A.—TABLE OF PENETRATION INTO WROUGHT IRON.

[Computed by Royal Artillery Formula: Penetration = $\sqrt[1.6]{\frac{V^2P}{2g \times 2r\pi \times 2240 \times K}}$ in inches.]

V = velocity in feet per second. P = weight of shot in pounds. r = radius of shot in inches. K = coefficient = 2.53.

Guns	Cal.	Weight of—		Ranges, in yards.														
		Powder.	Shot.	At muzzle.	600	1,200	1,800	2,400	3,000	3,600	4,200	4,800	5,400	6,000	6,600	7,200	7,800	8,400	9,000
	Inch.	Lbs.	Lbs.																
100-ton Armstrong, chambered	17.75	550	2,022	34.76	33.20	31.67	30.26	28.89	27.55	26.30	25.13	24.02	22.99	22.04	21.23	20.47	19.79	19.18	18.60
100-ton Armstrong, chambered	17.75	776	2,000	37.52	35.81	34.14	32.59	31.11	29.66	28.30	27.00	25.73	24.55	23.47	.....	.....	.....	.....	.....	.....
81-ton Woolwich, chambered	16	445	1,760	32.60	31.23	29.89	28.64	27.42	26.24	25.14	24.07	23.10	22.19	21.35	.....	.....	.....	.....	.....	.....
38-ton Woolwich, chambered	12.5	200	800	22.07	20.83	19.65	18.54	17.52	16.60	15.73	14.98	14.32	13.75	13.26	..	.....	.....	.....	.....	.....
71-ton (40-centimeter) Krupp, chambered	15.75	485	1,715	33.52	32.12	30.76	29.46	28.22	27.04	25.89	24.79	23.76	22.80	21.89	.....	.....	.....	.....	.....	.....
51-ton (35.5-centim'r) Krupp, chambered	14	298	1,146	26.86	25.54	24.27	23.08	21.94	20.86	19.86	18.94	18.07	17.34	16.69	.....	.....	.....	.....	.....	.....
18-ton (24-centimeter) Krupp, chambered	9.45	165	474	20.42	19.31	18.27	17.28	16.34	15.46	14.65	13.90	13.22	12 63	12.14	.....	.....	.....	.....	.....	.....
8-inch converted U. S. R., unchambered	8	35	180	10.23	9.22	8.36	7.67	7.14	6.72	6.35	6.01	5.71	5.43	5.17	.....	.....	.....	.....	.....	.....

TABLE B.—TABLE OF PENETRATION INTO WROUGHT IRON.

[Computed from the recent English formula: Penetration = $\sqrt[2.035]{\frac{V^2P}{2g \times 2r\pi \times 2240 \times 0.86}}$.]

V = velocity in feet per second. P = weight of shot in pounds. r = radius of shot in inches.

NOTE.—This applies to penetration into thick armor plates.

Guns.	Cal.	Weight of—		Ranges, in yards.															
		Powder.	Shot.	At muzzle.	600	1,200	1,800	2,400	3,000	3,600	4,200	4,800	5,400	6,000	6,600	7,200	7,800	8,400	9,000
	Inch.	Lbs.	Lbs.																
100-ton Armstrong, chambered	17.75	550	2,022	27.68	26.70	25.73	24.82	23.93	23.06	22.23	21.45	20.70	20.00	19.34	18.78	18.26	17.78	17.35	16.93
100-ton Armstrong, chambered	17.75	776	2,000	29.38	28.32	27.28	26.30	25.35	24.42	23.54	22.68	21.84	21.05	20.32	.....	.....	.....	.....	.....	.....
81-ton Woolwich, chambered	16	445	1,760	26.30	25.43	24.57	23.76	22.96	22.18	21.44	20.72	20.06	19.44	18.86	.....	.....	.....	.....	.....	.....
38-ton Woolwich, chambered	12.5	200	800	19.36	18.49	17.67	16.88	16.14	15.47	14.84	14.27	13.78	13.34	13.03	.....	.....	.....	.....	.....	.....
71-ton (40-centimeter) Krupp, chambered	15.75	485	1,715	26.89	26.00	25.13	24.29	23.48	22.70	21.94	21.21	20.51	19.85	19.23	.....	.....	.....	.....	.....	.....
51-ton (35.5-centim'r) Krupp, chambered	14	298	1,146	22.59	21.71	20.86	20.05	19.27	18.52	17.82	17.17	16.57	16.01	15.54	.....	.....	.....	.....	.....	.....
18-ton (24-centimeter) Krupp, chambered	9.45	165	474	18.21	17.43	16.68	15.97	15.28	14.63	14.02	13.46	12.94	12.48	12.09	.....	.....	.....	.....	.....	.....

TABLE OF FIRE OF THE 35.5-CENTIMETER (14-INCH) KRUPP GUN, 30-CALIBER LENGTH.

[Extract from Krupp's Publication of the Meppen firing, No. XXXIV. Meters and kilograms converted into English measures.]

Date of firing, Meppen.	Weight of—		Angle of elevation.	Range.	Deviation to—		Area containing 50 per cent. of hits.			Time of flight.
	Powder.	Shot.			Left.	Right.	Height.	Width.	Length.	
1882.	*Pounds.*	*Pounds.*	° ′	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	″
April 20 and May 8	220.4	1,157.5	4 07	8,658		42.3				
Do	464.5	1,157.5	3 40	9,094	1.9					
Do	297.6	1,157.5	2 55	8,104	7.8					
Do	313.5	1,157.5	2 45	8,058		36.0				
Do	319.6	1,157.5	2 48	8,435						
Do	319.6	1,157.5	2 48	8,359						
Do	317.4	1,157.5	2 17	7,103		4.9				
Do	313.5	1,157.5	2 17	6,837						
Do	313.5	1,157.5	2 17	6,801			1.6	2.5		
Do	313.5	1,157.5	2 17	6,778						
Do	313.5	1,157.5	4 00	11,063	8.5					
Do	313.5	1,157.5	4 00	11,083	9.1			1.6	83.6	7.8
Do	313.5	1,157.5	4 00	10,961	6.8					7.8
Do	313.5	1,157.5	6 00	15,433		8.8				10.8
Do	313.5	1,157.5	6 00	15,354		7.2		5.5	72.5	10.6
Do	313.5	1,157.5	6 00	15,469		0.98				10.9
May 10	264.5	1,157.5	8 00	17,307		95.8				
Do	313.5	1,157.5	6 00	15,521		63.0				
Do	313.5	1,157.5	6 00	15,610		61.3		3.9	52.8	
Do	313.5	1,157.5	6 00	15,557		56.7				
Do	313.5	1,157,5	12 00	25,137		65.3				19.8
Do	313.5	1,157.5	12 00	25,033		61.3		17.0	125.9	19.9
Do	313.5	1,157.5	12 00	25,252		86.0				19.8
Do	313.5	1,157.5	18 00	33,647	3.6					29.6
Do	313.5	1,157.5	18 00	33,346	14.7			11.6	261.0	29.8
Do	313.5	1,157.5	18 00	33,739		5.6				29.6

NOTE.—On April 20, 1882, the following initial velocities, with different powder-charges, were obtained:

Weight of—		Initial velocity.	Remarks.
Shot.	Powder-charge.		
Pounds.	*Pounds.*	*Feet.*	
1,157.5	220.4	1,434.6	
	264.5	1,571.1	
	297.6	1,680.4	
	313.5	1,717.1	Mean of 4 rounds.
	317.4	1,755.8	
	319.6	1,735.5	Mean of 2 rounds.

TABLE OF FIRE OF THE 30.5-CENTIMETER (12-INCH) KRUPP GUN, 35-CALIBER LENGTH.

[Extract from Krupp's Publication of the Meppen firing, No. XXXI. Meters and kilograms converted into English measures.]

Date of firing, Meppen.	Weight of—		Angle of elevation.	Range.	Deviation to—		Area containing 50 per cent. of hits.		
	Powder.	Shot.			Left.	Right.	Height.	Width.	Length.
1882.	*Pounds.*	*Pounds.*	° ′	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
March 23	324.8	1,003	2 18	6,745	.....	.....			
Do	324.8	1,003	2 18	6,758	.....	.....			
Do	324.8	1,003	2 18	6,820	.....	.....	3.47	1.04	.....
Do	324.8	1,003	2 18	6,840	.....	.....			
Do	324.8	1,003	2 18	6,830	.....	.....			
March 30	324.8	1,003	15 00	31,233	164.0	.....			
Do	324.8	1,003	15 00	30,672	91.8	.....			
Do	324.8	1,003	15 00	31,046	105.9	.....	.....	31.5	288.3
Do	324.8	1,003	15 00	31,088	121.4	.....			
Do	324.8	1,003	15 00	30,862	114.8	.....			
Do	324.8	1,003	15 00	31,075	144.3	.....			
Do	324.8	1,003	15 00	30,511	157.4	.....			
Do	324.8	1,003	15 00	30,544	164.0	.....	.....	9.74	317.5
Do	324.8	1,003	15 00	30,721	150.9	.....			
Do	324.8	1,003	15 00	30,892	150.9	.....			

NOTE.—On March 23, 27, and 29, 1882, twenty rounds were fired; weight of powder-charge, 324.8 pounds; weight of projectile, 1,003 pounds, which gave a mean initial velocity of 1,720 feet.

TABLE OF FIRE OF THE 28-CENTIMETER (11-INCH) KRUPP GUN, 35-CALIBER LENGTH.

[Extract from Krupp s Publication of the Meppen firing, No. XXXII. Meters and kilograms converted into English measures.]

NOTE.—Krupp's tables gave each round.

Date of firing, Meppen.	Weight of—		Angle of elevation.	Mean range.	Mean deviation to—		Area containing 50 per cent. of hits.			Mean time of flight.	Remarks.
	Powder.	Shot.			Left.	Right.	Height.	Width.	Length.		
1882.	*Pounds.*	*Pounds.*	° ′	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Seconds*	
June 1	253.5	652.5	1 54	5,964	0.0	0.0	.....	.....	.....	.....	1 round.
Do	253.5	652.5	2 11	6,819	.....	.....	1.6	1.3	31.2	.....	Mean of 9 rounds.
June 23	253.5	652.5	2 11	6,740	.....	.....	2.3	1.7	.....	.....	Mean of 5 rounds.
June 2	246.9	652.5	2 14	6,798	.....	.....	2.6	1.9	60.0	.....	Mean of 8 rounds.
Do	244.7	652.5	2 18	6,951	.....	.....	5.4	2.1	134.8	.....	Mean of 6 rounds.
June 1	253.5	760.5	2 23	6,780	.....	.....	2.1	1.1	36.1	.....	Mean of 10 rounds.
June 23	253.5	652.5	2 48	8,844	5.9	.....	.....	18.7	124.6	.....	Mean of 3 rounds.
Do	253.5	652.5	4 45	13,820	.....	65.6	.....	.....	.....	.....	Mean of 2 rounds.
June 6	253.5	760.5	4 51	13,057	.....	9.8	.....	.....	.....	8.8	1 round.
Do	253.5	760.5	4 54	13,276	.....	.....	6.85	3.1	68.9	8.8	Mean of 8 rounds.
Do	253.5	760.5	5 00	13,569	.....	54.8	.....	.....	.....	8.8	1 round.
June 5	253.5	652.5	8 00	20,357	58.4	.....	.....	12.1	106.3	14.0	Mean of 5 rounds.
June 23	253.5	652.5	8 00	20,293	.....	66.3	.....	18.6	124.6	.....	Do.
June 5	253.5	760.5	8 30	20,368	55.1	.....	.....	9.8	159.1	14.6	Mean of 10 rounds.
June 3	253.5	760.5	17 15	33,630	574.0	.....	.....	26.6	296.6	27.6	Mean of 5 rounds.
Do	253.5	652.5	17 15	34,158	627.9	.....	.....	32.8	275.5	27.8	Do.
Do	246.9	652.5	17 15	33,956	655.4	.....	.....	27.9	328.0	27.8	Do.
Do	244.7	652.5	17 15	33,761	634.4	.....	.....	33.8	228.9	27.8	Do.
Do	242.5	652.5	17 15	33,782	612.0	.....	.....	30.5	410.4	27.7	Do.

NOTE.—On June 1, 2, and 6 the following initial velocities were obtained:

Weight of shot.	Weight of powder-charge.	Initial velocity.	Remarks.
Pounds.	*Pounds.*	*Feet.*	
652.5	242.5	1,825.1	Mean of 8 rounds.
652.5	244.7	1,823.4	Mean of 6 rounds.
652.5	246.9	1,824.7	Mean of 8 rounds.
652.5	253.5	1,842.4	Mean of 10 rounds.
760.5	253.5	1,734.0	Mean of 20 rounds.

RECORD OF FIRING OF THE 100-TON ITALIAN GUN.

[Extracts from "Latest Studies and Experiments with reference to the material of the G. R. C. gun, of 45 centimeters." Giornale di Artiglieria e Genio, ottobre 1881.]

Table I. gives the mean result of four series of five shots each, fired at different ranges for accuracy, July, 1880.

TABLE I.

Mean range ..... in meters..	1,950	4,133	5,811	7,777
Width of rectangle (in deviation)..... do.....	8	13.2	8.7	6.2
Length of rectangle (in range)..... do.....	27	57	33	68

Table II. gives ranges, angles of fall, remaining velocities, and time of flight corresponding to different angles of elevation up to 15° 48′, the initial velocity being 451 meters and weight of projectile 1,000 kilograms.

TABLE II.

Range.	Angles of elevation.	Angles of fall.	Remaining velocities.	Time of flight.
m.	° ′	° ′	*m.*	*Seconds.*
500	0 39	.....	436	1.1
1,000	1 22	1 35	422	2.2
1,500	2 09	2 22	408	3.5
2,000	2 55	3 13	395	4.7
3,000	4 36	5 14	371	7.4
4,000	6 26	7 43	350	10.2
5,000	8 25	10 33	332	13.2
6,000	10 37	13 48	318	16.4
8,000	15 48	22 25	296	23.6

The following table gives the results of fire of the 45-centimeter gun, G. R. C., breech-loading, in the series of preliminary fires against a movable target on the sea:

TABLE III.

No. of round.	Distance to the target.	Result of the fire. Too long.	Too short.	To right.	To left.	Remarks.
	m.	*m.*	*m.*	*m.*	*m.*	
59	2,650	50	.....	.....	.....	
60	1,100	0	0	0	0	
61	1,860	50	.....	.....	5	
62	2,930	.....	20	0	0	
63	2,760	15	.....	8	.....	
64	3,030	..	30	0	0	Shot fired too soon.
65	3,850	70	.....	0	0	
66	4,100	80	.....	0	0	
67	4,900	20	.....	10	.....	50m } Correction in range.
68	5,100	50	.....	10	.....	100m }
69	5,380	150	.....	.....	20	100m }
71	1,180	30	.....	0	0	
72	2,980	.....	50	.....	10	
73	3,570	70	.....	.....	5	
74	4,170	30	.....	5	.....	
75	4,430	100	.....	.....	8	
76	4,950	30	.....	.....	7	
77	4,900	10	.....	8	.....	100m } Correction in range.
78	3,980	.....	50	6	.....	100m }
79	4,000	.....	50	.....	3	100m }
80	2,980	20	.....	3	.....	
81	2,770	.....	25	.....	4	
82	2,800	.....	45	2	.....	
83	1,950	40	.....	3	.....	
84	1,420	35	.....	.....	6	
85	2,760	15	.....	.....	5	
86	2,350	.....	15	5	.....	
87	3,100	100	.....	.....	6	

This gun has been fired at angles varying from 10° elevation to 6° depression. The time of loading was reduced to a minimum of 4½ minutes. Three shots fired against sand for penetration traversed the mass 12 meters and entered the rock behind it from 0 to 30 centimeters.

TABLE OF FIRE OF THE 32-CENTIMETER ITALIAN RIFLED GUN.

[Giornale di Artiglieria e Genio, ottobre 1881.]

TABLE IV.

Range.	Angle of elevation.	Angle of fall.	Remaining velocity.	Time of flight.	Energy.		Area containing 50 per cent. of the shots.		
					Total.	Per centimeter of circumference.	Height.	Width.	Length.
m.	° ′	° ′	*m.*	*Seconds.*	*Tonn-met.*	*Tonn-met.*	*m.*	*m.*	*m.*
500	0 31.2	0 45	422	1.2	3,151	31.54	.....	.....	.....
1,000	1 18.6	1 38	401	2.4	2,845	28.48	0.2	0.2	6
1,500	2 09.6	2 37	382	3.6	2,582	25.85	0.5	0.4	10
2,000	3 04	3 44	366	5.0	2,370	23.73	1.0	0.6	15
2,500	4 02	4 58	351	6.3	2,180	21.82	1.7	0.9	20
3,500	6 10.2	7 47	328	9.3	1,904	19.05	4.1	1.5	30
5,000	9 54.6	13 00	299	14.3	1,582	15.83	.....	3.2	48
7,000	16 09	21 52	271	22.0	1,299	13.01	.....	7.1	79
8,000	20 03	27 14	260	26.5	1,196	11.97	....	9.8	100

TABLE OF BALLISTIC DATA FOR HEAVY ITALIAN AND FOREIGN GUNS.

[Giornale di Artiglieria e Genio, ottobre 1881.]

TABLE V.

	Krupp, 24-centimeter, 30 caliber.	Italian, 32-centimeter.	Krupp, 24-centimeter, 35 caliber.	Krupp, 30.5-centimeter, 25 caliber.	French, 34-centimeter.	Krupp, 30.5-centimeter, 30 caliber.	Krupp, 35.5-centimeter, 25 caliber.	Krupp, 30.5-centimeter, 35 caliber.	Woolwich, 81-ton.	Italian, 45-centimeter.	Krupp, 40-centimeter, 25 caliber.	Armstrong, 45-centimeter (Dudlio).	Krupp, 35.5-centimeter, 30 caliber.	French, 42-centimeter.	Krupp, 35.5-centimeter, 35 caliber.	French, 37-centimeter.	Krupp, 40-centimeter, 30 caliber.	Krupp, 40-centimeter, 35 caliber.
Caliber ....millimeters.	240	321	240	305	340	305	355	305	406	450	400	450	355	420	355	370	400	400
Weight of gun.....tonn.	19	38	21.5	32	47.6	42.9	51.3	48.4	81.2	103	72	102	68	72.2	76.5	76.4	97.2	109.5
Weight of projectile..kilos.	160	350	160	329	420	329	525	329	770	1,000	740	908	525	780	525	612	740	740
VELOCITY.																		
Initial.....in meters.	575	453	605	500	500	575	500	605	460	455	500	490	575	510	605	600	575	605
At 500 meters... .....do...	544	431	572	473	473	551	480	579	444	440	482	472	554	510	583	572	556	585
At 1,000 meters .....do...	515	411	541	455	455	527	460	555	427	425	465	455	534	490	562	551	538	566
At 1,500 meters.....do...	487	392	513	433	435	505	442	531	412	410	447	439	515	472	542	530	521	548
TOTAL ENERGY.																		
Initial.....in tonn-meters.	2,698	3,663	2,989	4,195	5,353	5,544	6,718	6,138	8,216	10,558	9,433	11,117	8,847	11,152	9,794	11,232	12,470	13,805
At 500 meters.....do...	2,415	3,330	2,673	3,754	4,792	5,085	6,191	5,630	7,718	9,874	8,765	10,320	8,221	10,340	9,102	10,210	11,673	12,923
At 1,000 meters.....do...	2,165	3,015	2,391	3,474	4,424	4,664	5,686	5,164	7,159	9,211	8,157	9,584	7,640	9,549	8,458	9,476	10,927	12,097
At 1,500 meters.....do...	1,934	2,744	2,143	3,146	4,053	4,278	5,251	4,737	6,669	8,573	7,538	8,922	7,100	8,861	7,860	8,767	10,228	11,323
ENERGY PER CENTIMETER OF SHOT'S CIRCUMFERENCE.																		
Initial.....in tonn-meters.	35.8	36.9	39.6	43.8	50.5	57.8	60.2	64.0	65.1	74.9	75.0	78.9	79.3	84.5	87.8	96.6	99.2	109.8
At 500 meters.....do...	32.0	33.0	35.4	39.2	44.9	53.7	55.6	58.7	60.5	69.8	69.7	73.0	73.7	78.4	81.6	87.9	92.9	102.8
At 1,000 meters.....do...	28.7	29.9	31.7	36.3	41.5	48.7	51.0	53.9	56.1	65.1	64.9	67.8	68.5	72.4	75.8	81.5	86.9	96.2
At 1,500 meters.....do...	25.6	27.2	28.4	32.8	37.9	44.6	47.1	49.4	52.3	60.6	60.0	63.1	63.7	67.2	70.5	75.4	81.4	90.1
THICKNESS OF IRON PLATE JUST PENETRABLE BY CHILLED IRON PROJECTILE.																		
Fire normal:																		
At muzzle.in centim'rs.	40.9	41.5	43.1	45.5	49.2	52.8	54.0	55.8	56.3	60.6	60.7	62.4	62.6	64.7	66.1	69.4	70.5	74.5
At 500 meters.....do...	38.5	39.8	40.5	43.0	46.1	50.6	52.2	53.2	54.1	58.4	58.4	59.6	60.1	62.3	63.5	66.2	68.1	71.8
At 1,000 meters...do...	36.3	37.1	38.3	41.1	44.1	48.2	49.5	50.7	52.4	56.3	56.1	57.4	57.8	59.2	61.0	63.4	65.7	69.3
At 1,500 meters...do...	34.5	35.3	36.0	39.0	42.1	46.0	47.8	48.6	50.1	54.2	53.9	55.1	55.6	57.2	58.7	60.7	63.4	66.9
Fire 30° from normal:																		
At muzzle.in centim'rs.	35.1	35.7	38.2	39.1	42.3	45.4	46.4	48.0	48.4	52.1	52.2	53.7	53.8	55.6	56.8	59.7	60.6	64.1
At 500 meters.....do...	33.1	33.7	34.8	37.0	39.6	43.5	44.9	45.7	46.5	50.2	50.2	51.2	51.7	53.6	54.6	56.9	58.6	61.7
At 1,000 meters...do...	31.2	31.9	32.9	35.3	37.5	41.4	42.6	43.6	45.0	48.4	48.2	49.4	49.7	50.9	52.5	54.5	56.5	59.6
At 1,500 meters...do...	29.7	30.3	31.0	33.5	36.2	39.6	41.1	41.8	43.1	46.6	46.3	47.4	47.8	49.2	50.5	52.2	54.5	57.5
Fire 45° from normal:																		
At muzzle.in centim'rs.	28.0	29.0	30.2	31.8	34.4	37.0	37.8	39.0	39.4	42.4	42.5	43.7	43.8	45.3	46.3	48.6	49.3	52.1
At 500 meters.....do...	26.9	27.4	28.3	30.1	32.3	35.4	36.5	37.2	37.9	40.9	40.9	41.7	42.1	43.6	44.4	46.3	47.7	50.3
At 1,000 meters...do...	25.4	26.0	26.8	28.8	30.9	33.7	34.6	35.5	36.7	39.4	39.3	40.2	40.5	41.4	42.7	44.4	46.0	48.5
At 1,500 meters...do...	24.1	24.7	25.2	27.3	29.5	33.2	33.5	34.0	35.1	37.9	37.7	38.6	38.9	40.0	41.1	42.5	44.4	46.8

The velocities recently attained by the 81-ton Woolwich and 100-ton Armstrong exceed those assumed in the foregoing Table V, and would therefore give greater penetration than those recorded therein.

The preceding tables, prepared in this office, with initial velocities absolutely attained in firing, and penetrations calculated therefrom for the guns enumerated, exhibit the relative value of the guns as at that date in that respect. If those different guns should be lengthened to 35 calibers, to give greater initial velocities, say 605 meters, assumed for the Krupp guns, they will give penetrations corresponding thereto.

The question in comparing guns is, which will endure continuously the heavy charges required to give the high velocities to produce the maximum penetration?

CLXL

Iron Plates just penetrable by the guns
of projectiles as given, corresponding to
of accompanying table marked: A .

in inches into thin Armor Plates

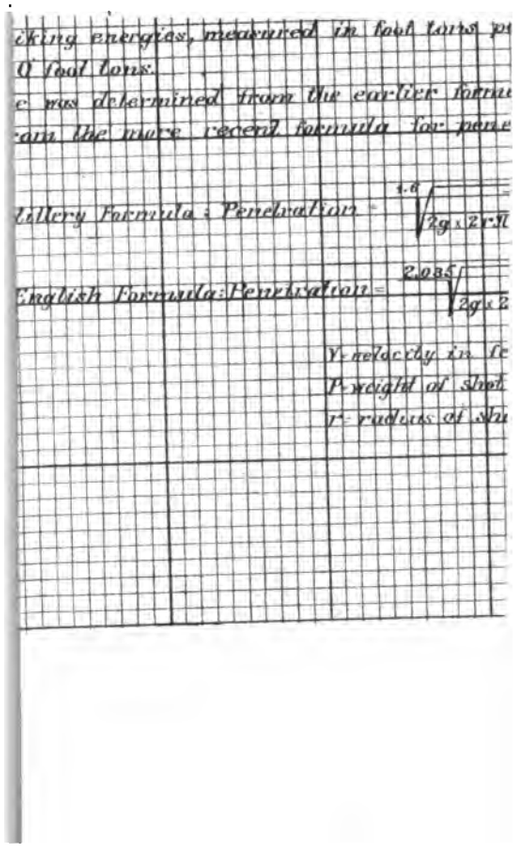
xK

as: r= radius of shot in inches, coefficient K= 2.53

m
eight from Plates just penetrable
ties and weights of projectiles as
yards.
data of accompanying table marked: B

$\frac{.2240 \times K}{r}$

in inches into thick Armor Plates.
r = radius of shot in inches. coefficient K = 0.86

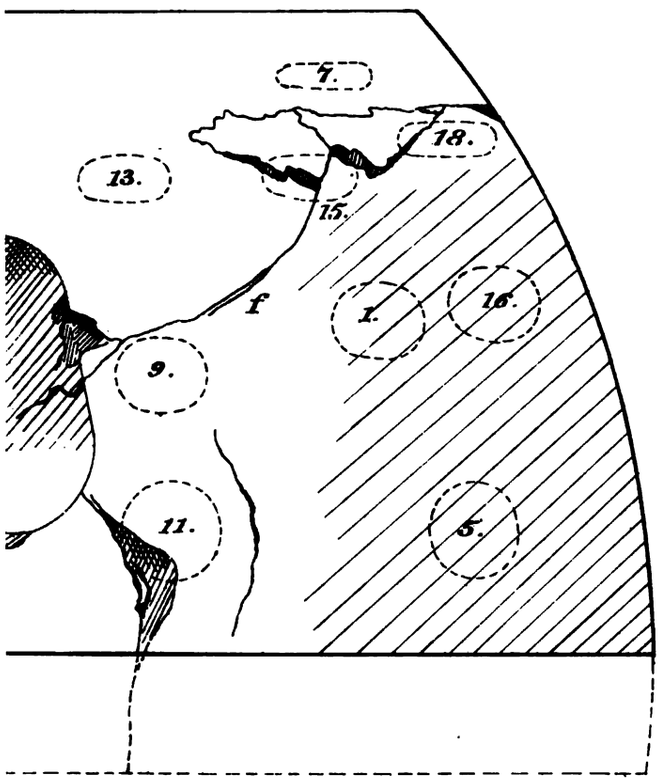

cking energies, measured in foot tons p
0 foot tons.
e was determined from the earlier formu
ean the more recent formula for pene

illery Formula : Penetration = $\frac{1.6}{\sqrt{2g \times 2r \cdot}}$

nglish Formula: Penetration = $\frac{2.085}{\sqrt{2g \times 2}}$

V = velocity in fe
P = weight of shot
r = radius of sh

Plate III.



RASURE PLATE
5.4 IN.

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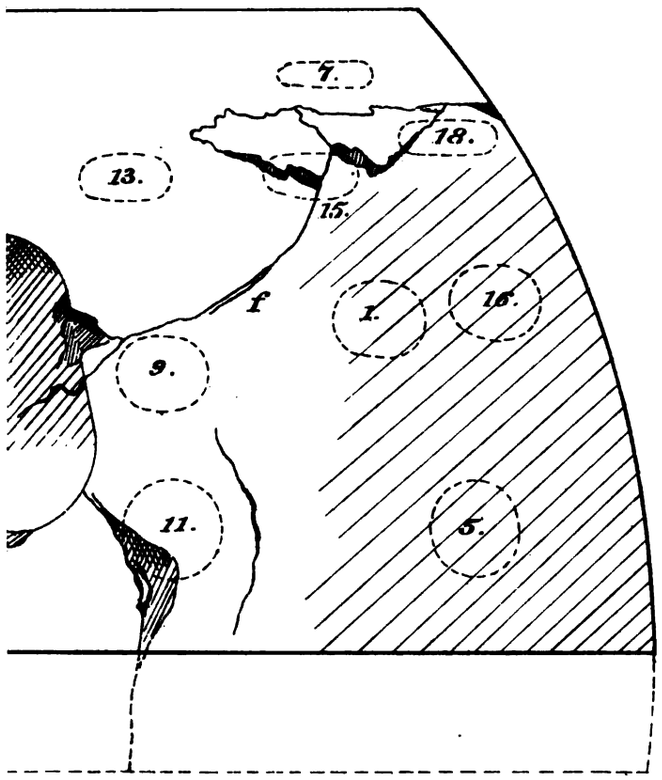
Plate III.



RASURE PLATE
5.4 IN.

1883
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